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NINTH ANNUAL REPORT

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AGRICULTURAL COLLEGE

. . . OF THE . . .

UNIVERSITY OF WYOMING

. . . AND OF THE . . .

WYOMING
AGRICULTURAL EXPERIMENT STATION

FOR THE FISCAL YEAR ENDING JUNE 30, 1899.

LARAMIE, WYO.,
THE REPUBLICAN BOOK AND JOB PRINT.
1899.

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LETTER OF TRANSMITTAL.

To His Excellency,
Hon. De Forest Richards,
Governor of Wyoming,
Cheyenne, Wyoming.

As President and Director I have the honor to present the Ninth Annual Report of the Agricultural College and the Agricultural Experiment Station of Wyoming. This report covers the work of the College and Station from July 1, 1898, to July 1, 1899.

Copies will be sent also to all Agricultural Colleges, to the Secretary of the Treasury, to the Secretary of the Interior, and to the Secretary of Agriculture, in accordance with Sections 3 of Acts of Congress of August 30, 1890, and March 2, 1887.

Respectfully submitted,

Elmer E. Smiley

University of Wyoming,
June 30, 1899.

Faculty of the College of Agriculture.

ELMER E. SMILEY, D. D., President,
Professor of Political Science.
BURT C. BUFFUM, M. S.,
Professor of Agriculture and Horticulture.
AVEN NELSON, M. S., M. A.,
Professor of Biology.
HENRY MERZ, M. A.,
Professor of German and Social Science.
EDWIN E. SLOSSON, M. S.,
Professor of Chemistry.
WILBUR C. KNIGHT, M. A., F. G. S. A.,
Professor of Geology.
IRENE M. MORSE, M. A.,
Professor of French and History.
CHARLES B. RIDGAWAY, M. A.,
Professor of Mathematics and Physics.
LOUISE H. MOREY, B. A.,
Professor of English.

Professor of Military Science and Tactics.
WILLIAM F. GILKISON, B. S., M. E.,
Associate Professor of Drawing and Industrials.
JUNE E. DOWNEY, M. A.,
Instructor in English and Philosophy.
CHARLES H. FULTON, M. E.,
Assistant in Geology.
DANIEL C. ROYER, Q. T.,
Instructor in Bookkeeping.

NINTH ANNUAL REPORT

. . . OF THE. . .

College of Agriculture of the University of Wyoming.

I hereby submit the ninth annual report of the College of Agriculture of Wyoming, in compliance with enactment of Congress. Following this report is a technical paper presented by Mr. Elias Nelson as a thesis for the M. A. degree. While it reveals a large amount of research, yet it cannot be considered experimental and is therefore classed with the Agricultural College report rather than with the report of the Experiment Station.

INCEPTION OF THE COLLEGE.

The first president of the University of Wyoming, when constructing the various courses of the institution, in accordance with the act of incorporation, planned for distinct schools of agriculture and mechanic arts. These departments did not obtain much growth until 1891. On the 10th of January of that year they were organized into separate colleges by an act of the Legislature of Wyoming, which vested the control of the appropriations from the Morrill Act of Congress in the Board of Trustees of the State University. The Morrill Act, approved August 30, 1890, was intended to grant an endowment for agricultural and mechanical colleges in addition to that obtained by a land grant on July 2, 1862.

PRESENT MANAGEMENT AND COURSE.

The Board of Trustees, whose names appear on a preceding page, have been changed since the last report by the appointment of Judge J. A. Riner and Hon. S. Conant Parks in the place of Prof. J. O. Churchill and Hon. J. A. McAvoy, whose terms of office had expired; and by the election of Hon. Thomas T. Tynan as State Superintendent of Public Instruction. The faculty of the College, with the position held by each member, appears on another page. Whenever a consolidation of classes has been possible, the professor of a subject has been employed as in the College of Liberal Arts. Thus considerable expense has been saved to the state and an economical management effected.

The various courses in agriculture and mechanical engineering have been appended to this part of the report, and will be found to present as high a standard as those of any similar institution in the country. The model offered by the Committee on Courses of the American Association of Agricultural Colleges and Experiment Stations has been closely followed.

EQUIPMENT.

The laboratory facilities of the Agricultural College are the same as those of the University and are very good in most branches of science; the comparatively small number of students in the higher classes gives opportunities for personal attention from instructors and the use of better apparatus than in most large institutions.

The Physical Laboratory is fitted with water, gas, and electricity, and accommodates students in sections of twenty-four at once. The method of conducting the laboratory work in elementary classes is that which is sometimes known as the "collective system." Under this method all are engaged on the same experiment at the same time, thus allowing the teacher to instruct the whole class at once on difficult points, and still leaving him free to devote the greater portion of his time to assisting those who need particular attention. Each elementary student performs a series of experiments in accurate measurements and weights;

friction machines, and composition of forces; properties of matter; the pendulum; heat; magnetism; electricity, testing of resistance and making of cells, etc. Advanced students have the use of accurate instruments for electrical measurements, motor, dynamo, and statical electrical machines, X-ray apparatus, phonograph, telephones, electrical heater, siren, etc. The field work in surveying included in this department covers the use of the Wye-level, compass, transit, and solar attachment.

The new equipment added to the Department of Physics during the past year consists of the following apparatus: A Kater's pendulum, an optical bench and accessories, a differential galvanometer, a Waltenhafer pendulum, a Mack's wave machine, a quadrant electrometer, an 18-light (16 candle power each) dynamo, a ½ horse power electrical motor, and a Tesla vibrator in addition to numerous smaller pieces used in demonstrations.

The Geological Laboratory contains facilities for studying mineralogy, geology, and paleontology. Students of mineralogy determine in the first term some fifty minerals with the blow-pipe and familiarize themselves with two hundred more. For advanced students in mineralogy there are two petrographical microscopes, with rock sections and instruments for preparing the sections. The collection of rock speciments for class use now numbers six hundred. The opportunities for field work in geology are fully described in the department statement. The paleontological collection is being rapidly enlarged from Wyoming fields and already affords ample material for original work.

The Chemical Laboratory has locked desks, provided with gas and water, for thirty-six students. Elementary students perform about one hundred experiments, many of them quantitative, and then make complete qualitative analysis of twenty mixtures. Advanced students have all necessary apparatus for difficult organic and inorganic preparations, quantitative analysis, including organic, gas, sugar, and electrolytic analysis, and determination of heat of combustion with the bomb calorimeter.

The Biological Laboratory is provided with sinks, gas, water, excellent compound and dissecting microscopes, microtomes, turntables, waterbaths, charts, models, photographic apparatus, and the necessary appliances for bacteriological work.

The Machine Shops are run as nearly as possible to correspond with actual manufacturing establishments. In the wood room each student has his own chest of tools for bench work and has the use of turning lathes, pattern maker's trimmer, mortising machine, pony planer, short jointer, boring machine, band saw, scroll saw, variety wood worker, and circular saw with two cross cut and two rip saws. The iron room is provided with a 24 inch x 24 inch x 6 foot planer, a 25 inch back geared power feed drill press, a universal milling machine, a 14 inch x 6 foot engine lathe, a 16 inch x 6 foot engine lathe, a power back saw, a twist drill grinder, a power pipe-threading machine, a 14 inch sensitive drill, and an emery grinder with two 14 inch wheels. The foundry contains a Whiting cupola, 32 inch outside diameter lined down to a 23 inch, which has a capacity of melting from 1,000 to 2,000 pounds of iron an hour. It is also provided with six 50 pound ladles, one 200 pound ladle, core oven, flasks, riddles, bellows, and all tools necessary to operate a first-class foundry. There are also complete sets of piping tools for steam fitting and a forge for sharpening and tempering. Advanced classes have the use of an American Thompson Indicator and Arndt's Econometer with which to take indicator cards and test the efficiency of boilers.

MUSEUM.

The Agricultural Museum occupies a well-lighted room on the third floor of the Main Building. The cases are large and built of substantial oak. They contain a collection of specimens of the cultivated crops and wild grasses of Wyoming. With the collection of crops are the seeds of each in neat exhibit bottles. The exhibit also includes some rare seeds from Africa, Japan, and other foreign countries. The cereals and forage crops raised on the Laramie Experiment Farm occupy one case. They are arranged in an artistic manner and contain heads of grain that for size and perfection of shape are rarely surpassed. The exhibition of wild grasses consists of a portion of those sent to the World's Fair in 1893, which received the award of a medal and diploma. The fruits of our state are as yet not represented, but some work has been done in reproducing the fruit in plaster, thus making it possible to keep them on exhibition in permanent form.

The collection contained in this museum is instructive to the student and gives the stranger a good idea of what Wyoming is capable of in agriculture.

The Herbarium now contains about 16,000 specimens. It is a fair working collection of the plants of the Western United States, being rich in those of the Rocky Mountains and especially of Wyoming. A steady growth is maintained, collections of much value being added each year. It represents the flora of Wyoming so far as known and is becoming of more and more interest to students who desire to make a special study of the plants of this range, especially so since it contains the types of many new species recently described. The herbarium is open to University students and others whose previous training is such as to enable them to profit by its use.

NEW BUILDING.

The last legislature provided for an appropriation for a new building, which will probably be a Science Hall, and will include the Museum. This will relieve the pressure of the over-crowded laboratories, and will afford for the first time an opportunity of exhibiting to the public the agricultural specimens, minerals and gigantic fossil saurians which have hitherto been stored away for lack of room.

Departmental Statements.

The following is a detailed report of each department of the College of Agriculture:

POLITICAL SCIENCE.

This department includes civic, public law, political economy, and sociology. Its aim has been to cultivate independent thought and foster intelligent citizenship. After the origin and growth of each subject has been investigated, and the general principles have been acquired, the student is required to apply the principles thus obtained to leading problems of the present day. Debates, public and private, form an important feature of the courses. The following subjects are offered:

II. *Constitutional Law.* Cooley; Black. Examination of cases; lectures; debates. [Elective for agricultural seniors.]

III. *International Law.* Walker; Gallaudet; Woolsey; Snow's Cases. Lectures; debates; theses. [Elective for agricultural seniors.]

IV. *Political Economy.* Ely's Introduction; Walker; Marshal; Gregory. Lectures; debates; theses. [Required of agricultural and mechanical seniors.]

VII. *Comparative Government.* Wilson's The State; Wenzel's Comparative View of Government; Bagehot's

English Constitution; Helie's Les Constitutions de France; Nicolson's Sketch of the German Constitution; Bryce's American Commonwealth. Lectures; theses. [Elective for seniors.]

SOCIAL SCIENCE.

The aim of this department is to familiarize students with the history of social development and to encourage investigation of the principles on which social progress depends. After a thorough grounding in the fundamental facts, the student is expected to observe the social phenomena about him and to study the various problems in an independent manner. Inasmuch as sociology is a science of recent birth and its theories are constantly expanding, much of the class-work consists of lectures and theses. The following subjects are offered:

I. *Principles of Sociology* Small and Vincent; Giddings; Kidd's Social Evolution. Lectures; debates; theses. [Elective for agricultural seniors.]

II. *Social Problems.* Study of crime, suicide, insanity, pauperism, charities, temperance, socialism, education, etc. Discussion; theses. [Elective for agricultural seniors who have taken I and Philosophy IV.]

III. *Social Philosophy.* Lectures on social theories, old and new, and on the aims of society. Discussions; theses. [Elective for agricultural seniors who have taken I and II.]

PHILOSOPHY.

The work of this department is intended to furnish an acquaintance with philosophic thought, to afford a training in the methods of investigating philosophic phenomena, and to imbue the student with the latest methods of education. Special attention is given to physiological psychology. The work in this subject is illustrated by charts and models of the brain and sense organs and by the introduction of various experiments. In teaching logic more time than formerly is given to inductive reasoning, as a perfect knowledge of this form is especially helpful to scientific students and to those intending to do research work in philosophy.

I. *Psychology, Introductory.* James's Briefer Psychology, or Titchener's Outlines of Psychology. Collateral Readings. The purpose of this course is to give the student insight into the principal psychological conceptions and methods, and practice in simple psychological experimentation. [Required of agricultural juniors.]

II. *Psychology, Advanced.* Investigation of special topics. Reading, observation, experiment. [Elective for those students who have taken I; winter term; five times a week.]

III. *Logic.* Jevons-Hill's Elements of Logic as text, with Fowler, Bain, Sidgwick, and others for reference. Treatment of the proposition, immediate and mediate inference, the hypothesis, arguments, and fallacies. Special attention to the principles and methods of induction. [Elective for agricultural seniors.]

IV. *Ethics.* Markenzie's Manual of Ethics, or Muirhead's Elements of Ethics. Lectures and discussions with readings from Plato, Aristotle, Kant, Mill, Spencer, and others. A critical examination of different ethical theories, cheifly, Hedonism, ancient and modern; Rigorism; and Evolutionary Utilitarianism. [Elective for juniors and seniors; spring term; five times a week.]

BIOLOGY.

The department of biology as at present organized includes botany, zoology and physiology.

Even in the introductory courses laboratory work is made a prominent feature in order that from the first students may become self-reliant.

The equipment of the department has been adequate to the demands made upon it, and as new necessities arise in connection with the several courses, they will be supplied as far as possible from the resources at command.

One of the two rooms of the department is a convenient lecture room having, among its other equipments, a lantern with microscope attachment. This enables the instructor to illustrate on the scheen by both lantern and microscope slides the subject under discussion.

The laboratory is large and well lighted, and is furnished with working tables and desks. The following subjects are offered:

BOTANY.

I, II, III. *General.* The purpose of this introductory course is to give a general view of the entire field. The work progresses from the simplest plants to the more specialized forms. The first and second terms are devoted to the morphology and physiology of plants, and the third term to the ecology and classification of phanerogams. [Required of agricultural freshmen.]

IV, V. *Histology and Physiology.* A course in histology and experimental physiology of the higher plants, together with a consideration of some of the special problems of plant reproduction and morphology. [Elective for agricultural seniors.]

VI. *Mycology.* Fungi in general, but with special attention paid to those of economic importance. [Elective for agricultural seniors.]

ZOOLOGY.

I, II, III. *General.* The aim is to acquaint the student with the main facts of animal structure, physiology, and classification by means of lectures, laboratory work on typical animal forms, and prescribed reading. It is a prerequisite for the other courses in Zoology. [Required of agricultural sophomores.]

IV, V. *Comparative Anatomy of Vertebrates.* A study of the principal problems connected with the successive modification of the different organs in the several classes of animals. [Elective for all who have taken I, II, and III.]

VI. *Microscopical Anatomy.* Microscopical technique, methods of investigation, and the preparation of sections of normal vertebrate tissues. [Elective for agricultural seniors.]

PHYSIOLOGY.

I. *Physiology and Hygiene.* This course assumes on the part of the student such general knowledge of the human body as is provided in the grammar grades of our best public schools. The course aims to review the more important subjects to consider the problems of hygiene that are of special interest to all students. [Repuired of preparatory agricultural students.]

AGRICULTURE.

The instruction in agriculture aims to give the student the greatest possible knowledge of the science of agricultural practice in the time given. The larger part of the instruction is by lectures. Where text-books are used, they are supplemented by lectures, keeping the student abreast of the times.

Up to the senior year, as often as the other work will permit, students are required to work in the green-house or upon the agricultural grounds or experiment farm two hours each afternoon. As far as possible, the work is made to illustrate the branch being taught. The agricultural museum furnishes material with which to illustrate the study of farm crops and the agricultural productions of the world.

In the work upon the farm and the instruction in the class-room, the methods and results of the Experiment Station are always before the student. These will afford him much general information regarding the practice of agriculture in this region, and will give him an insight into the way by which important facts are deduced from the mass of daily observations and notes. The following subjects are required:

I. *History of Agriculture.* Taught by lectures and reference books, such as Goss's Principles of Plant Culture, and Johnson's How Plants Grow, and How Plants Feed. A brief outline of the history of agriculture, followed by a thorough course in the principles of plant cultivation and growth. [Required of agricultural sophomores.]

II *Soils, Tillage, and Fertilizers.* Taught by lectures and reference books, such as King's The Soil, and Storer's Agriculture. [Required of agricultural sophomores.]

III. *Farm Crops.* Lectures. Planting, irrigating, harvesting, and marketing; laying out and improving farms; farm management and farm accounts. The students' practice will include setting up and running farm machinery, planting and irrigating crops properly. [Required of agricultural sophomores.]

IV, V. *Breeds of Live Stock.* Curtiss's Breeds of Live Stock, Warfield's Cattle Breeding, and Miles' Stock Breeding, supplemented by lectures and practice in judging by scale of points. [Required of agricultural juniors.]

VI. *Stock Feeding and Dairy Management.* Armsby's Cattle Feeding, Henry's Cattle Feeding, and lectures. [Required of agricultural juniors.]

HORTICULTURE.

The instruction in this department aims to give the student a good general foundation in the science of gardening, plant cultivation, fruit raising, landscape and ornamental gardening. During the spring term of one year, two hours of laboratory work each week in the multiplication of plants, grafting, budding, and making cuttings are required. The following subjects are offered:

I. *Plant Forcing.* Study of green-houses and hot-beds, and of the cultivation and propagation of vegetables and small fruits. Lectures. [Required of agricultural juniors.]

II. *Pomology.* Pruning, grafting, budding, cuttings, and orcharding. Lectures. [Required of agricultural juniors.]

III. *Landscape and Ornamental Gardening.* Lectures [Elective for agricultural seniors.]

IV. *Thesis Work.* Pollination, cross fertilization, variation, or other advanced subject. [Elective for agricultural seniors.]

ENTOMOLOGY.

This department aims to give the student an insight into insect life, and to afford some knowledge of economic entomology through the study of injurious insects and the means for their extermination. The following subjects are required.

I. *Elementary.* Packard's Entomology, with Comstock for reference. Lectures. [Required of Agricultural juniors.]

II. *Economic Entomology.* Smith's Economic Entomology, supplemented by lectures. [Required of agricultural juniors.]

IRRIGATION.

The object of this department is to give a general idea of the principles of irrigation practice and water measurement.

I. *Principles.* Effects of water on soil and crops, and measurement of water. Wilson's Irrigation Engineering. Lectures, reference reading, and practical work. [Required of agricultural juniors.]

CHEMISTRY.

The work of all courses in the department of chemistry is experimental and inductive so far as consistent with the acquirement of the necessary amount of general information. Students are from the first encouraged to work independently on lines of investigation in which they are specially interested.

The department of chemistry occupies four rooms in the south end of the Main Building. One room contains the analytical balances and the chemical reference library, the second is devoted to the experimental work of the Wyoming Agricultural Experiment Station, the third is a lecture room, and the fourth and largest room is fitted up for the classes in qualitative and quantitative analysis. The department is well equipped with apparatus for research and analytical work in organic and inorganic chemistry. The following subjects are offered:

I, II. *Elementary.* Storer and Lindsay. The aim of this course is to give students a knowledge of the laws of chemical change, a practical familiarity with the principal elements and compounds, and skill in the manipulation of apparatus. [Required of agricultural and mechanical sophomores.]

III. *Qualitative Analysis.* Caldwell's Qualitative Analysis. Students acquire the ability to detect the ordinary acids and bases in any substance. [Required of agricultural and mechanical sophomores.]

IV. *Quantitative Analysis.* Caldwell and Fresenius. Twenty simple gravimetric and volumetric determinations. [Elective for students who have taken III.]

VI. *Inorganic Preparations.* Erdmann's Anleitung zur Darstellung chemischer Präparate. Preparation of a number of difficult compounds and elements. [Open to students who have taken III; spring term; laboratory work ten hours a week.]

VII. *Organic Chemistry.* Remsen's Organic Chemistry. Lectures and recitations on the compounds of carbon. [Required of agricultural juniors; fall term; five times a week.]

VIII. *Organic Preparations.* Gatterman; Practical Methods in Organic Chemistry. [Open to students who have taken VII; winter term; laboratory work ten hours a week.]

XI. *Agricultural Chemistry.* The chemistry of plant growth, and the application of chemical principles to practical agriculture, with special reference to the problems of the arid region. [Required of agricultural juniors; winter term; lectures three hours and laboratory work four hours a week.]

XII. *Applied Chemistry.* Lectures on chemical processes and manufacturers not included in metallurgy, and on methods of analysis and control. Most attention is paid to subjects of practical importance in Wyoming; such as petroleum and its products; coal, gas, and coke; building stone and cements; alkalies and acids; beet sugar; glass; air and water supply. [Required of mechanical juniors.]

GEOLOGY.

Most of the instruction in this department is given by lectures, but text-books are used for reference together with the latest geological reports.

The location of the Agricultural College is exceptionally advantageous for the study of geology. Only a few miles east of the Laramie mountains rise nearly 2,000 feet above the campus, while to the westward the Medicine Bow mountains rise 5,000 feet. Both of these mountain ranges are mineralized, and mining has been carried on for many years. They furnish rich fields for the student of structural and dynamical geology, as well as for those who wish to study almost new Archean exposures. Flanking these ranges are Paleozoic, Mesozoic, and Cenozoic rocks that have been exposed by the mountain making and subsequent erosion, so that a student may easily make himself familiar with the entire series of Rocky Mountains sedimentary rocks. The working collections of rocks and fossils in the department are not large, but are well selected and are increasing in size very rapidly. The collection of Mesozoic invertebrates is very complete and the collection of Jurassic vertebrates is the second in size in the United States. To those who wish to study economic geology special inducements can be offered, since ores of economic value are numerous, and are only a short distance away from the University. The plains are also well supplied with mines of coal and deposits of clay, gypsum, and building stones.

The following list of books is used for reference and text work in this department: LeConte, Dana, Geikie, Kayser-Lake, Lapparent, Tarr, Zittel, and Nicholson and Lydekker. The following subjects are offered:

I. *Dynamical and Structural.* Geological forces, conditions in which stratified rocks are found, and general topography. Lectures; Le Conte and Dana as texts. [Required of agricultural juniors.]

II. *Mineralogical.* Elementary study of mineralogy, in which a student is required to determine fifty species of common minerals with the blow-pipe. Lectures; Crosby and Brush as texts. [Required of agricultural juniors.]

III. *Historical.* Study of fossilized life associated with stratified rocks, and methods of determining formations from associated fossil life. Lectures; LeConte and Dana as texts. [Required of agricultural juniors.]

IV. *Economic.* Study of the minerals of economic importance and methods of preparing them for the market. Lectures; Kemp and Tarr as texts. [Elective for agricultural seniors.]

V. *Paleontological.* Elementary course in paleontology. Lectures; Nicholson and Lydekker as text. [Elective for agricultural seniors.]

VI. *Advanced.* Course arranged to suit the needs of students. One week in the field. [Elective for agricultural seniors.]

HISTORY.

The purpose of the department of history is to create a taste for historical reading and give the ability to comprehend rightly the events of the times by applying the experience of the past to the conditions and problems of today. The aim is not the accumulation of a mass of facts and dates, but the acquisition of a right camprehension of great historical events.

Text-books are used, especially in the preparatory classes; but the study of the assigned lessons is supplemented by reading different authorities on the same subject and by lectures. The historical library has been greatly enlarged during the past year and is at the disposal of the students in this department. The following courses are offered:

I. *England.* Montgomery's English History. [Required of preparatory students.]

II, III. *Mediaeval and Modern.* Myer's Mediaeval and Modern History. [Required of preparatory students.]

IV. *Greece.* Myers' History of Greece; Guerber's Mythology. [Elective for agricultural seniors.]

V. *Rome.* Allen's History of Rome. [Elective for agricultural seniors.]

VI, VII, VII. *Middle Ages.* Thatcher and Schwill. Lectures and supplementary reading. [Elective for agricultural seniors.]

ENGLISH.

The aim of the preparatory work in this department is to teach the students to understand and use the English language correctly and to coultivate in them a taste for the best literature. A thorough mastery of English grammar is required before entrance to the Preparatory Year.

The student's work in literature is made to furnish the occasion as well as the material for the preparation of essays. These essays are subject to criticism both in the class and with the individual writers.

The formal study of rhetoric is designed to ground the student in the principles of English composition and to cultivate his literary sense by analytical study.

The work in oratory is of a practical character. An effort is made to secure reading that shall be intelligent, natural and forcible, and to develop spontaneous expression from the mental side. The student meets the instructor personally for rehearsal and criticism.

The following subjects are open:

I, II, III. *Composition and Rhetoric.* Constant practice in writing. Hill's Foundations of Rhetoric. Selections from the following American authors are read, and passages are memorized: Irving, Bryant, Longfellow, Whittier, Lowell, Holmes. Supplementary reading. [Required of agricultural and mechanical preparatory students; three terms; five times a week.]

VII, VIII, IX. *Literary Masterpieces.* Reading, composition, memorizing selections. The books prescribed are: Dryden's Palamon and Arcite; Pope's Translation of the Iliad, Books I, VI, XXII, XXIV; The Sir Roger de Coverly papers in the Spectator; Goldsmith's Vicar of Wakefield; Scott's Ivanhoe; DeQuincey's Flight of a Tartar Tibe; Cooper's Last of the Mohicans; Selections from Tennyson's Idyls of the King; Hawthorne's House of Seven Gables. [Required of agricultural freshmen; three terms; once a week.]

X, XI, XII. *History of Literature.* History of English and American literature. Selected reading; composition;

recitations. [Required of agricultural sophomores and mechanical juniors.]

XIII, XIV, XV. *English Poets.* Chaucer and Spenser; Burns, Wordsworth, Coleridge, Byron, Keats, Shelley; Tennyson and Browning. Critical reading of selected poems with study of the literary art of the poets. Comparative study. Papers on topics connected with works read. Reading by the professor with requisite comments. Special attention is paid to the grammar and pronunciation of Chaucer's works. [Required of agricultural sophomores; three terms; three times a week.]

XIX, XX, XXI. *Oratory.* Study of selections from great English and American orators. Composition. Recitations and declamations which are subject to criticism by the professor and by the class. Every member of this class is required to deliver in public one original oration at the end of each term. [Required of agricultural and mechanical seniors; three terms; once a week.]

MATHEMATICS.

The instruction in mathematics aims to develop the powers of mental concentration, to give facility in attacking original problems, and ability to recognize the difference between logical proof and presumptive evidence, and to form in the students the habit of expressing his ideas in concise mathematical language.

All fundamental concepts are presented in as many different forms as possible, with fullness of explanation and variety of illustration, so that the student may thoroughly understand all the principles involved.

The following subjects are required:

I, II, II, IV. *Algebra.* Wentworth, Wells, Taylor, or Charles Smith. Fundamental operations. Fractions and fractional equations, simultaneous equations of the first degree. Problems involving two unknown numbers, simple indeterminate equations, involution and evolution. Radical and imaginary expressions, quadratic equations, ratio and proportion. [Required of preparatory students and freshmen.]

V, VI. *Plane Geometry.* Wells, Wentworth, Chauvenet, or Beman and Smith. Much of the time is devoted to solving original propositions, and when time permits, some of the modern methods and the geometrical theory of proportion are taught. [Required of freshmen.]

VII. *Advanced Algebra.* Well's College Algebra. Progressions, binomial theorem, convergent and divergent series, undetermined coefficients, logarithms, permutations and combinations, summation of series, determinants, theory of equations, solution of higher equations. [Required of mechanical sophomores.]

IX. *Trigonometry.* Well's New Trigonometry. The development of the general formulae and their application to the solution of triangles, polygons, and original field problems. [Required of agricultural juniors and mechanical sophomores.]

X. *Analytical Geometry.* Wentworth's Analytical Geometry. The analytical geometry of the straight line, circle, and conic sections; including a general discussion of the general equation of the second degree, and an introduction to the geometry of three dimensions. [Required of mechanical juniors, elective for agricultural seiors.]

XI, XII. *Calculus.* Osborne's Calculus. Differentiation of functions, successive differentiation, indeterminate forms, development of functions in series, maxima and minima, functions of two or more variables, tangents, normals, asymptotes, direction of curvature, singular points, curve tracing, evolutes, envelopes, and order of contact. Integration, application to geometry and mechanics, successive integration, integration of rational fractions, integration by rationalization, by parts and by series, lengths and areas of plane curves, areas of surfaces of revolution, and volumes of solids. [Required of mechanical juniors, elective for agricultural seniors.]

PHYSICS.

The aims of this department are to cultivate in the student habits of thoughtful observation, intelligent and rapid manipulation, and to give him a general knowledge of natural phenomena. In all courses the subjects are studied from the experimental side, the student spending at least one-half of the time allotted to the work in the laboratory under the direct supervision of the professor in charge.

The following subjects are offered:

I, II, III. *Elementary.* Carhart and Chute's Elements of Physics; Allen's Laboratory Physics. The properties of matter; mechanics of solids and liquids. Heat, sound, and light. Magnetism and electricity. [Required of freshmen.]

IV, V, VI. *General.* Barker's Physics. Outlined experiments with reference to laboratory manuals. Physical quantities, kinematics, dynamics, work and energy, attraction and potential, and properties of matter. Energy of mass vibration, molecular kinetic energy, radiant energy. Energy of aether-stress, energy of aether-vortices, energy of aether-flow, and the electromagnetic character of radiation. [Required of mechanical juniors and elective for agricultural seniors.]

VII. *Electric Measurements.* Measurements of resistances, calibration of amperemeters and voltmeters, calculation of the electromotive force of batteries and dynamos, magnetic determinations, heating effect of currents, etc. [Elective for agricultural seniors.]

MECHANICS.

The aim of the instruction in this department is to give the student a thorough insight into the general principles governing prime movers and mechanical movements, and acquaintance with the methods in which these principles may be applied and combined in order to produce the desired effect in all branches of engineering. Instruction is also given in subjects which are rather more technical than theoretical, and the application of theory to practice is never lost sight of. The work is fully illustrated by frequent reference to the engineering and mechanical equipment of the university and other available sources.

The following subjects are required of mechanical students:

I, II. *Founding.* Lectures on core making, loam, dry and green sand moulding; cast iron; flasks, facing, finishing, etc.; alsoon preparing, charging, tapping out, and stopping up the cupola. [Required of mechanical freshmen.]

III. *Iron Working Machines.* Joshua Rose's Complete Practical Machinist. Study of the use and care of iron machinery, particularly the lathe; speed of different parts; screw cutting, turning eccentrics, taps and dies; fitting connecting rods; pumps, etc. [Required of mechanical juniors; fall term; five times a week.]

IV. *Elements of Mechanism.* Stahl and Woods' Elementary Mechanism. Study of the elementary principles underlying mechanical movements and the modes of communicating motion. [Required of mechanical juniors; winter term; five times a week.]

V. *Steam Boilers.* A Treatise on Steam Boilers, by Wilson and Flather. A general study of the different forms of modern steam boilers, their construction, advantages, and disadvantages. [Required of mechanical seniors; fall term; five times a week.]

VI. *Steam Engines.* The Steam Engine, by Holmes. The mechanism and principles brought into use in the design of the modern steam engine. Gidding's adjustable model for universal valve movements is used in the class room. Careful study is also made of working engines. [Required of mechanical seniors; fall term; five times a week.]

VII. *Steam Engine Indicators.* The Slide Valve, by Rose, and Hemenway's Steam Engine Indicators. As many different engines are tested as time will permit. [Required of mechanical seniors; winter term; five times a week.]

VIII. *Engineering Materials.* Merriman's Mechanics of Materials. Theory of resistance of different materials, and study of those principally used in engineering, especially brick, stone, timber, iron, and steel. [Required of mechanical seniors; winter term; five times a week.]

IX. *Hydraulics.* A Treatise on Hydraulics, by Merriman. The flow of water through tubes, in pipes, canals, rivers, and over weirs; measurement of water power and pressure of flowing water. [Required of mechanical seniors; spring term; five times a week.]

X. *Thermodynamics of Gases.* A study of the properties of gases, saturated vapor, and superheated steam, and their application to the steam engine. [Elective for mechanical seniors; spring term; five times a week.]

DRAWING.

The aim of the department of drawing is to develop and quicken the ability of observation and to follow as closely as possible the line of work done in the practical drafting rooms of machine shops.

The following subjects are required:

I. *Freehand Drawing.* Drawing from models and copies, with which the department is well supplied. [Required of agricultural freshmen, and of mechanical preparatory students.]

II. *Freehand Drawing.* Sketching parts of machines to be used in instrumental drawing. [Required of agricultural fresmen, and of mechanical preparatory students.]

III. *Use of Instruments.* A short course in straight and curved lines and lettering. [Required of agricultural freshmen and of mechanical freshmen.]

IV. *Geometrical Constructions.* Geometrical problems used in instrumental drawing. [Required of mechanical freshmen.]

V. *Descriptive Geometry.* An elementary course in projection. [Required of mechanical freshmen.]

VI, VII. *Instrumental Drawing.* Detailed copies of parts of machines. Drawing to scale of parts of machines from sketches taken in the shops by the students. [Required of mechanical sophomores.]

VIII, IX. *Shades and Engineering Colors.* Drawing and tinting machines and parts of machines. [Required of mechanical sophomores and juniors.]

X. *Parts of Machines.* Designing gears, cams, and parts of machines which apply to the study of Mechanics II. [Required of mechanical juniors.]

XI. *Blue Prints.* Tracing and making drawings to be used in the shops. [Required of mechanical juniors.]

XII. *Machine Designing.* Designing a boiler or some simple machines; the design to be as original as possible. [Required of mechanical seniors.]

XIII. *Steam Engine Drawing.* This subject is to accompany the work in Mechanics V and VI. [Required of mechanical seniors.]

INDUSTRIALS.

This department is intended to simplify mechanical engineering by teaching practical work in connection with the theory. It aims also to present the practical side of production by running the machine shops as nearly as possible on the principle of actual manufacturing establishments.

I, II. *Wood Working.* Lectures on the care and management of carpenters' tools; exercises in lining, planing, sawing, notching, splicing, mortising, and tenoning. Bench work in wood; exercises in dovetailing, framing, paneling, and special work for the department. [Required of agricultural and mechanical preparatory students.]

III. *Wood Turning.* Exercises in straight and curved turning, compound curves, etc. [Required of agricultural and mechanical preparatory students.]

IV. *Pattern Making.* A large variety of patterns, including parts of machines, are made for use in the foundry. [Required of mechanical freshmen.]

V. VI. *Foundry Practice.* Exercises in moulding, pouring, charging and managing the cupola. The castings obtained are used by the students in the machine room. [Required of mechanical freshmen.]

VII. *Iron Work.* Exercises in filing and chipping, and the use of the drill press. [Required of mechanical sophomores.]

VIII. *Iron Planing.* Exercises and special work. [Required of mechanical sophomores.]

IX. *The Engine Lathe.* An elementary course; tapering, screw cutting, etc. [Required of mechanical sophomores.]

X. *The Engine Lathe, Advanced.* Special work; turning up parts of machines, and work for the department. [Required of mechanical juniors.]

XI. *Milling.* Exercises in milling, sawing, gear cutting, spiral cutting, and work on parts of machines. [Required of mechanical juniors.]

XII. *Engineering Laboratory.* Testing the efficiency of boilers, and inspection visits. [Required of mechanical juniors.]

XIII. *Engineering Laboratory.* Testing steam engines, learning the principles and operation of the steam engine indicator and rigging; inspection visits. [Required of mechanical seniors.]

XIV. *Shop Engineering.* General work in shop management, lining shaftings, and setting machines; inspection visits. [Required of mechanical seniors.]

XV. *Experimental Laboratory.* A thesis is produced in connection with experimental work. [Required of mechanical seniors.]

Special subjects of experiment are arranged for those who have taken the baccalaureate of science in mechanics and wish to take graduate work.

MILITARY SCIENCE AND TACTICS.

The department of Military Science and Tactics is established in accordance with the requirements of an act of Congress donating public lands to colleges, one of the conditions being that military tactics shall be taught. It is under the control of an officer of the regular army, detailed by the War Department for its duty, without any expense to the State, under the provisions of Section 1225, Revised Statutes of the United States. One hundred and fifty Springfield rifles (cadet pattern; similar to those used at West Point) and equipments, and canon and sabres for artillery and cavalry practice, are loaned to the college by the U. S. Ordnance Department. An allowance of ammunition is annually supplied by the general government for purposes of target practice. All students are required to drill throughout the year. The cadet officers are appointed by the commandant of cadets, subject to the approval of the President. The commissioned officers are usually selected from the senior class, the sergeants from the junior class, and the corporals from the sophomore class, general merit and military efficiency being the qualifications considered.

Besides obtaining the excellent physical results which follow systematic and regular military training, the *morale* of the students will thus be improved. The virtues of patriotism, honor, and truthfulness are cultivated, and habits of neatness, promptness, and obedience are insisted upon.

The rules prescribed by the President of the United States for the government of officers of the army detailed as Professors of Military Science and Tactics require the following course of instruction:

1. The course of instruction shall be both practical and theoretical, and shall be so arranged as to occupy at least one hour per week for theoretical instruction, and at least two hours per week for practical instruction.

2. The practical course in infantry shall embrace small-arm target practice, and, as far as possible, all the movements prescribed by the drill regulations of the United States army applicable to a battalion. Instruction in artillery shall embrace, as far as practicable, such portions of the United States drill regulations as pertain to the formation of detachments, manual of the piece, mechanical maneuvers, aiming drill, saber exercise, and target practice. Instruction should also include the duty of sentinels, and where practicable, castrametation. Such instruction shall be given by the Professor of Military Science and Tactics personally, or under his immediate supervision.

3. Theoretical instruction shall be by recitations and lectures personally conducted and given by the Professor of Military Science and Tactics, and shall include, as far as practicable, a systematic and progressive course in the following subjects: The drill regulations of the United States army, the preparation of the usual reports and returns pertaining to a company, the organization and administration of the United States army, and the elementary principles governing in the art of war.

The military department shall be subject to inspection under the authority of the President of the United States; such inspection shall be made, when practicable, near the close of the college year. The inspecting officer shall, upon his arrival at the institution, report to the President or other administrative officer in order to obtain from him the necessary facilities for the performance of his duty. A copy of the report of inspection will be furnished the President of the institution by the War Department.

Military drill has become a feature of all the courses in the University and it is required that all students appear at the drill in uniform. Students are advised to come to the college without specially providing themselves with new clothes and to arrange to wear the cadet uniform habitually while at college.

The cost of the uniform is about $18.00. The grade of suiting, including the cap, wears well and proves to be economical.

All male students are expected to provide themselves with uniforms. It consists of a blouse, trousers, and cap, modeled after the West Point uniform, with raised gilt buttons.

COURSE IN MILITARY SCIENCE.

Practical.—Cadets are divided into two classes, First Year and Subsequent Year Cadets.

For all cadets: Practical instruction comprises the schools of the soldier, squad, and company in normal and extended order (Infantry Drill Regulations), guard mounting and guard duty, gallery and range target practice.

For Subsequent Year Cadets: In addition to the above comprises artillery drill, saber exercise, and military signaling with flag and heliograph.

Theoretical.—Cadets are divided into four classes. The winter term is especially devoted to this instruction, which includes the following:

First Year Cadets: Infantry Drill Regulations, includin the schools of the soldier, squad, and company, in normal and extended order.

Second Year Cadets: School of the battalion and ceremonies (Infantry Drill Regulations), and U. S. Manual of Guard Duty.

Freshman Class: "Elements of Military Science," Pettit.

Sophomore Class: U. S. Army Regulations, muster rolls and returns, etc., Military Law, and State Laws relating to the National Guard.

The corps of cadets has this year been divided into two companies, with the commandant acting as major. The number of young men in the drill has been seventy-seven.

THE LIBRARY.

The library, which is also the general reading room of the University, is situated on the second floor, in the north wing of the main building. This is a large, well- lighted and ventilated apartment. The college students use this room during vacant hours from 8:30 a. m. to 12 m., and from 1 to 3:15 p. m.

The students at all times during the day, for five days in the week, have free access to all the books and periodicals. Three volumes may be taken by any one individual and kept from the shelves for a period of two weekes: Books reserved at the instance of professors ac collateral reading for their courses are shelved in their respective rooms, and can be taken out only on application to such professors, who are responsible for them during the period of their reservation.

The library contains 7,000 bound volumes, and in addition several thousand unbound bulletins and reports on agricultural scientific subjects.

There have been added to the University library, during the fiscal year 1898-99, 800 bound volumes and 1,000 pamphlets, including Experiment Station bulletins and publications from the Department of Agriculture at Washington, D. C.

The following agricultural papers and Wyoming newspapers are sent to the University:

- Arkansas—
  - Farmer.
- California—
  - Press and Horticulturist.
  - The Call.
  - West American Science.
- Colorado—
  - Farmer.
  - The Field and Farm.
- Georgia—
  - The Southern Cultivator.
- Illinois—
  - Prairie Farmer.
  - Orange Judd Farmer.
  - Farmer's Review.
  - The Farmer's Magazine.
  - The Elgin Dairy Report.
  - Irrigation Age.
- Indiana—
  - Clover Leaf.
- Iowa—
  - Iowa Homestead.
- Kansas—
  - Farmer.
- Kentucky—
  - The Industrial American.
- Louisiana—
  - Planter.
- Maryland—
  - Farmer.
  - Southern State.
  - Baltimore Weekly Sun.
- Massachusetts—
  - Farm and Home.
  - Ploughman.
  - Our Grange Home.
  - American Cultivator.
  - New England Farmer.
- Michigan—
  - Grange Visitor.
- Missouri—
  - National Dairyman.
- Nebraska—
  - Western Resources.
- New Hamsphire—
  - Mirror and Farmer.
- New Mexico—
  - Southwestern Farm and Orchard.
- New York—
  - American Agriculturist.
  - Rural New Yorker.
  - Sugar Trade Journal.
- Ohio—
  - American Grange Bulletin.
- Ontario—
  - Farmers' Advocate.
- Pennsylvania—
  - Germantown Telegraph.
  - Public Ledger, daily.
- Virginia—
  - Southern Planter.
  - The Progressive South.
- Washington—
  - Northwest Mining Review.
- Wisconsin—
  - Hoard's Dairyman.
- State Papers—
  - Bill Barlow's Budget.
  - Boomerang.
  - Carbon County Journal.
  - Central Wyoming News.
  - Cheyenne Tribune.
  - Fremont County Gazette.
  - Laramie Times.
  - Newcastle News-Journal.
  - News-Register.
  - Otto Courier.
  - Rock Springs Independent
  - Rock Springs Miner.

Saratoga Lyre.
Saratoga Sun.
Sheridan Journal.
Sheridan Post.
Sun-Leader.
Wheatland World.
Wyoming Press.

The scientific and general periodicals taken by the library and kept on the tablese of the reading room are:

Agricultural Science.
American Gardening.
American Geologist.
American Historical Review
American Journal of Mathematics.
American Journal of Science
American Machinist.
American Naturalist.
Arena.
Art Interchange.
Asa Gray.
Atlantic Monthly.
Auk.
Berichte der Deutschen Chemischen Gesellschaft,
Biologisches Central-Blatt.
Book News.
Botanical Gazette.
Bulletin of the Torrey Botanical Club.
Carpenter and Builder.
Cassier's Magazine.
Century.
Cosmopolitan.
Cumulative Index.
Die Garten-laube.
Education.
Educational Review.
Electrical World.
Engineering Magazine.
Engineering Record.
Erythea.
Etude.
Fern Bulletin.
Fliegende Blaetter.
Forum.
Garden and Forest.
Germania.
Great Round World.
Harper's Monthly.
Harper's Weekly.
Home Study.
Journal of the Society of Chemical Industry.
Journal of the American Chemical Society.
Journal of the British Chemical Society.
Kunkel's Musical Review.
Literary Digest.
Meehan's Magazine.
Metal Worker.
Microscope.
Microscopical Journal.
Mining and Scientific News.
Monist.
Nation.
Nature.
North American Review.
Outlook.
Philosophical Review.
Photographic Times.
Physical Review.
Plant World.
Political Science Monthly.
Popular Science Monthly.
Power.
Psychological Review.
Public Libraries.

Quarterly Journal of Pure and Applied Mathematics
Review of Reviews.
Science
Scientific American and Supplement.
Scribner.
Sociology.
Studio.
St. Louis and Canadian Photographer.
Terrestrial Magnetism.
Young Men's Era.
Western Electrician.

The University now uses the Dewey Decimal Card Catalogue system, and in addition to the regular cards has those coming from the Department of Agriculture at Washington, containing a complete list of publications sent from that department and its several branches in connection with the Experiment Station work.

TREASURER'S REPORT.

UNIVERSITY OF WYOMING.
AGRICULTURAL COLLEGE.

Laramie, Wyoming, June 30, 1899.

Report of treasurer of said institution to the governor of the State of Wyoming of amount received under act of Congress of August 30, 1890, in aid of College of Agriculture and the Mechanic Arts, and of the disbursements thereof, to and including June 30, 1899.

Balance on hand July 1, 1898		$ 8,999.81
Date of receipt of installment for 1898-'99, July 28, 1898		24,000.00
Total available for year ending June 30, 1899		$32,999.81
Disbursements thereof for and during the year ending June 30, 1899.		
Agriculture	$ 1,083.60	
Mechanic Arts	2,829.37	
English Language	3,128.60	
Mathematical Science	1,149.29	
Natural or Physical Sciences	8,816.21	
Economic Sciences	3,503.41	
Total expended during the year		$20,510.48
Balance remaining unexpended July 1, 1899		$12,489.33

I hereby certify that the above account is correct and true, and, together with the itemized acocunt attached, truly represents the details of expenditures for the period and by the institution named, and that said expenditures were applied only to instruction in agriculture, the mechanic arts, the English language, and the various branches of mathematical, physical, natural, and economic science, with special reference to their application in the industries of life and to the facilities for such instruction.

John C. Davis, Treasurer.

Courses of Study.

AGRICULTURAL COURSE.

For explanation of the Roman numerals, see departmental statements on preceding pages. The Arabic numerals indicate the number of hours a week. Where no numeral appears, 5 is understood. Two hours of laboratory, shop or field work are counted as equivalent to one hour of recitation or lecture.

PREPARATORY YEAR.

FALL TERM.	WINTER TERM.	SPRING TERM.
History, I. English, I. Mathematics, I. Physiography, I. Industrials, I.	History, II. English, II. Mathematics, II. Physiography, II. Industrials, II.	History, III. English, III. Mathematics, III. Physiology, I. Industrials, III.

FRESHMAN YEAR.

Physics, I. Mathematics, IV. Drawing, I, 4. German, I. Botany, I, 4. English, VII, 1.	Physics, II. Mathematics, V. Drawing, II, 4. German, II. Botany, II, 4. English, VIII, 1.	Physics, III. Mathematics, VI. Drawing, III, 4. German, III. Botany, III, 4. English, IX, 1.

SOPHOMORE YEAR.

Zoology, I. German, IV. Chemistry, I. English, XIII, 3. Agriculture, I, 2.	Zoology, II. German, V. Chemistry, II. English, XIV, 3. Agriculture, II, 2.	Zoology, III. German, VI. Chemistry, III. English, XV, 3. Agriculture, III, 2.

JUNIOR YEAR.

Geology, I. Entomology, I, 3. Philosophy, I. Agriculture, IV, 2. Chemistry, VII.	Geology, II. Entomology, II, 3. Horticulture, I. Agriculture, V, 2. Chemistry, XI.	Geology, III. Horticulture, II, 3. Mathematics, IX. Agriculture, VI, 2. Meteorology, I, 2. Irrigation, I, 3.

SENIOR YEAR.

Political Science, IV. English, XIX, 1. Elective, 10 hours.	English, XX, 1. Elective, 15 hours.	English, XXI, 1. Elective, 15 hours.

MECHANICAL COURSE.

For explanation of the Roman numerals, see departmental statements on preceding pages. The Arabic numerals indicate the number of hours a week. Where no numeral appears, 5 is understood. Two hours of laboratory, shop or field work are counted as equivalent to one hour of recitation or lecture.

PREPARATORY YEAR.

FALL TERM.	WINTER TERM.	SPRING TERM.
History, I. English, I. Mathematics, I. Drawing, I. Industrials, I.	History, II. English, II. Mathematics, II. Drawing, II. Industrials, II.	History, III. English, III. Mathematics, III. Civil Government. Industrials, III.

FRESHMAN YEAR.

FALL TERM.	WINTER TERM.	SPRING TERM.
Physics, I. Mathematics, IV. Drawing, III. French, I, or German, I. Industrials, IV.	Physics, II. Mathematics, V. Drawing, IV, 3. Mechanics, I, 2. French, II, or German, II. Industrials, V.	Physics, III. Mathematics, VI. Drawing, V, 3. Mechanics, II, 2. French, III, or German, III. Industrials, VI.

SOPHOMORE YEAR.

FALL TERM.	WINTER TERM.	SPRING TERM.
Drawing, VI. French, IV, or German, IV. Chemistry, I. Mathematics, VII. Industrials, VII. Bookkeeping.	Drawing, VII. French, V, or German, V. Chemistry, II. Mathematics, VIII. Industrials, VIII. Bookkeeping.	Drawing, VIII. French, VI, or German, VI. Chemistry, III. Mathematics, IX. Industrials, IX.

JUNIOR YEAR.

FALL TERM.	WINTER TERM.	SPRING TERM.
Mechanics, III. Mathematics, X. Physics, IV. Drawing, IX. Industrials, X. English, X, 1.	Mechanics, IV. Mathematics, XI. Physics, V. Drawing, X. Industrials, XI. English, XI, 1.	Physiology and Hygiene. Mathematics, XII. Physics, VI. Drawing, XI. Industrials, XII. English, XII, 1.

SENIOR YEAR.

FALL TERM.	WINTER TERM.	SPRING TERM.
Political Science, IV. Mechanics, V. Mechanics, VI. Drawing, XII. English, XIX, 1. Industrials, XIII.	Mechanics, VII. Mechanics, VIII, or Mathematics, XIII. Drawing, XIII. English, XX, 1. Industrials, XIV.	Mechanics, IX. Mechanics, X, or Mathematics, XIV. Thesis. English, XXI, 1. Industrials, XV.

UNIVERSITY OF WYOMING.

LARAMIE, WYOMING.

REPORT OF THE PRESIDENT OF SAID INSTITUTION TO THE SECRETARY OF THE INTERIOR AND THE SECRETARY OF AGRICULTURE, AS REQUIRED BY ACT OF CONGRESS OF AUGUST 30, 1890, IN AID OF COLLEGES OF AGRICULTURE AND THE MECHANIC ARTS.

RECEIPTS FOR AND DURING THE YEAR ENDING JUNE 30, 1899.

1.	Balance on hand July 1, 1898, over and above all indebtedness (excluding funded debt, if any)	$10,686.82
2.	State aid; (a) Income from endowment granted by state	
	(b) Appropriation for current expenses	7,581.45
	(c) Appropriations for building or for other special purposes	
3.	Federal aid; (a) Income from land grant, act of July 2, 1862	
	(b) Additional endowment, act of August 30, 1890	24,000.00
	(c) For experiment stations, act of March 2, 1887	15,000.00
4.	Fees and all other sources	950.80
	Total	$58,219.07

EXPENDITURES FOR AND DURING THE YEAR ENDED JUNE 30, 1899.

(Not necessarily a balance sheet as compared with Division II above.)

1. Instruction in the subjects specified in Sec. 1, act of August 30, 1890*	$21,508.00
2. Instruction in all other subjects, if any, not mentioned in Question 1 of this series	4,100.00
3. Administrative expenses (President's, Secretary's, Treasurer's Librarian's salary, clerical service, fuel, light, etc.)§	3,300.00
4. Experiment Station	15,470.90
Total	$44,378.90

PROPERTY, YEAR ENDED JUNE 30, 1890.

Value of all buildings, $111,540; of other equipment, $46,500.

Value of above property (an estimate only is expected) not used for instruction in the subjects specified in section 1 of act of August 30, 1890, Buildings (all used); of other equipment, $16,000.

Total number of acres, 396; acres under cultivation, 180; acres used for experiments, 180; value of farm lands, $10,600; amount of all endowment funds, none.

Number of bound volumes, June 30, 1899, 7,000; pamphlets, 4,800.

FACULTY DURING THE YEAR ENDED JUNE 30, 1899.

	Male.	Female.
1. College of Agriculture and Mechanic Arts;		
(a) Preparatory classes	10	3
(b) Collegiate and special classes	10	3
(c) Total, counting none twice	10	3
2. Number in all other departments (excepting duplicates	3	1
3. Number of staff of Experiment Station	6	1

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*The answer to this question will include not only the amount received under the act of August 30, 1890 ("Morrill Act"), but also all amounts that are expended for the subjects specified in that act, irrespective of the character of the funds the amounts may be drawn from (State, tuition fees, or endowment, etc.)

§It may be convenient for many institutions to answer 2 and 3 as one question. Cost of new buildings is given under Division I.

STUDENTS DURING THE YEAR ENDED JUNE 30, 1899.

1. Colleges of Agriculture and Mechanic Arts:

	Male.	Female.
(a) Preparatory classes	10	1
(b) Collegiate and special classes	15	0
(c) Post graduate courses	0	0
Total, counting none twice	25	1
2. Number in all other departments	51	65

3. Number of students that pursued courses in agriculture, 2; mechanical engineering, 15; electrical engineering, 0; mining engineering, 10; architecture, 0; household economy, 0; veterinary science, 0; military tactics, 76. (It is not expected that the sum of these figures will equal the number of students given above.)
4. What degrees and how many of each kind were conferred in 1898-'99?

   On men, 3 (M. A., 1; B. S., 2.)
   On women, 3 (B. A., 3.)
5. What and how many honorary degrees were conferred in 1898-'99? None.

[Signed] ELMER E. SMILEY,
President.

REVISION

. . . OF THE . . .

Western North American Phloxes

BY

ELIAS NELSON, M. A.

PRESENTED AS A THESIS FOR THE MASTER'S DEGREE IN
THE BOTANICAL DEPARTMENT OF THE GRADUATE
SCHOOL OF THE UNIVERSITY OF WYOMING
AND PUBLISHED AS A PART OF THE
NINTH REPORT OF THE WYOMING
AGRICULTURAL COLLEGE.

ISSUED JUNE 1, 1899.

LARAMIE, WYOMING:
1899.

A REVISION

. . . OF THE . . .

Western North American Species of the Genus Phlox.

The only comprehensive treatment of the Western North American Phloxes is found in Dr. Gray's Revision of North American Polemoniaceae,* which is almost identically reproduced in the Synoptical Flora. The eastern species seem to have received more attention, and are apparently not so difficult to discriminate as the western, which have long been in need of careful study. Several species as constituted by Dr. Gray have been aggregates, and in the case of *P. Douglasii* the greatest confusion has prevailed. The greater abundance of material, resulting from recent collections in the west, has made it possible to attempt a more consistent disposition of such composite species. Since some work has been done of late in this genus, it has been thought that it might be of value to summarize our knowledge of the western Phloxes, as well as to make a critical study of the same.

This revision has been prepared at the University of Wyoming, and is based principally on the collection of Phlox from the herbarium of the Missouri Botanical Garden, and that in the herbarium of this university. Loan of specimens has also been had from the leading herbaria of the west. In all, about six hundred species have been examined. For loan of herbarium specimens I am much indebted to Dr. Wm. Trelease; C. V. Piper, Washington Agricultural College; Alice Eastwood, California Academy of

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*Proc. Am. Acad. 8: 253-258.

Sciences; C. S. Crandall, Agricultural College, Ft. Collins, Colo.; J. W. Blankinship, Agricultural College, Bozeman, Mont.; U. P. Hedrick, Utah Agricultural College; and Francis Ramely, University of Colorado. Specimens for the herbarium of the University of Wyoming have been secured from J. W. Blankinship; L. F. Henderson, University of Idaho; M. E. Jones, Salt Lake City, Utah, and J. M. Bates, Long Pine, Neb. My hearty thanks are also tendered to Dr. B. L. Robinson for his kindness in furnishing me with facts in regard to several questions of importance. Above all, I owe much to Prof. Aven Nelson, who has spared no pains to make this revision possible, and whose constant encouragement has been greatly appreciated.

With the exception of one species, *P. Siberica*, which is also found in the Arctic region of this continent, this genus is exclusively North American. Twelve species are found in eastern North America, while the western part has thirty-eight, only three of which extend as far east as Nebraska. About twelve of these thirty-eight are peculiar to the Rocky Mountain region, and six have Washington as their center of distribution. Of the latter, *P. linearifolia* merges into *P. longifolia* toward the east, and that in turn into *P. Stansburyi* further south. Similarly *P. speciosa*, belonging to the region drained by the Columbia River, is replaced by *P. occidentalis* in California and in Arizona by *P. Woodhousei*. *P. adsurgens* is a native of Oregon and northern California, and *P. dolicantha* and *P. Covillei* are found in Southern California. *P.tenuifolia* and *P.Woodhousei* are peculiar to Arizona. *P. canescens*, *P. austromontana* and *P. gladiformis* belong principally to the Great Basin, with Utah as their center of distribution. *P. nana* and *P. triovulata* are peculiar to New Mexico, and Texas is remarkable for having four species of annuals.

Descriptions have not been prepared of those species whose identity is well known, nor of those which have been recently named. Since the genus is not here treated of as a whole, no attempt has been made to assign subgeneric names to the groups which this revision covers. *P. Richardsonii* of the Arctic sea-coast and *P. alyssifolia** of Assiniboia are not included in the following synopsis, since specimens of these species have not been at hand.

KEY TO THE SPECIES.

1. **PERENNIALS; calyx teeth not setaceous-tipped.**

***Pulvinate-caespitose to loosely caespitose; the style usually much shorter than the corolla tube and nearly always shorter than the calyx.**

†Intercostal portions of the calyx not replicate.

‡Flowers solitary, the annual growth one-flowered.

||Leaves beset with woolly cobwebby hairs.

a. Densely arachnoid-lanate; leaves scale-like, ovate to lanceolate, much imbricated and crowded.

Leaves usually 4-ranked; corolla tube about twice the length of the calyx. P. bryoides.

Leaves not quadrifarious; corolla tube not exceeding the calyx. P. muscoides.

aa. Sparsely arachnoid-lanate; leaves subulate, usually distinctly bisulcate, less crowded.

Corolla tube about twice the length of the calyx. P. canescens.

Corolla tube little if at all exceeding the calyx. P. Hoodii.

|| ||Leaves not beset with woolly cobwebby hairs.

a. Leaves hispid-ciliate and often with short glandular-tipped hairs.

b. Leaves hispid-ciliate on the margins; the latter not noticeably thickened-cartilaginous.

Leaves oblong-linear, bisulcate, 5-6 mm. long. P. condensata.

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*Greene, Pitt. 3: 27 (1898).

Leaves lanceolate, oblong-linear or lance-linear, usually plane or somewhat grooved, 8-14 mm. long.
P. caespitosa.

bb. Surface of the leaves often hispid-ciliate as well as the margins; the latter thickened-cartilaginous.

Leaves crowded, oblong to ovate, 3-5 mm. long; flowers sessile. P. Covillei.

Stems 25-75 mm. high, the internodes longer than the leaves; in the variety minor the leaves are approximated and crowded and the flowers peduncled.
P. albomarginta.

aa. Sparsely lanate-ciliate on the calyx and usually at the base of the leaves.

b. Not glandular.

A pair of plane, oblong-linear leaves at each node with acerose ones in their axils; style nearly equalling the corrola tube. P. diffusa.

Loosely caespitose-spreading; leaves all acerose; style about half the length of the corolla tube.
P. Douglasii.

bb. Glandular.

Stems erect or ascending; these as well as the acerose leaves sparsely covered with short fine glandular-tipped hairs. P. Piperi.

aaa. Pubescent on the peduncles and calyx or entirely glabrour
P. multiflora.

‡‡Flowers not solitary, the annual stems 1-several flowered.

||Leaves with thickened cartilaginous margins.
P. albomarginata.

|| ||Leaves not with thickened cartilaginous margins.

Loosely caespitose-spreading; sparsely lanate-ciliate on the calyx and at the base of the leaves; the latter acerose. P. Douglasii.

Stems erect, from a rhizome; very sparsely lanate; leaves subulate, somewhat bisulcate, the larger ones often plane. P. andicola.

Very loosely caespitose-spreading with prostrate stems; pubescent, hirsute or glabrous, rarely glandular; leaves lanceolate or lance-linear, plane.
P. Kelseyi.

††Intercostal portions of the calyx replicate.

Canescent-pubescent or glabrate; corolla tube glabrous. **P. austromontana.**

Glandular throughout, corolla tube pubescent. **P. gladiformis**

**Loosely tufted, suffrutescent or nearly herbaceous, with erect or assurgent stems and usually distant leaves.

†Style long, equalling the corolla tube or at least longer than the ovary or stigmas.

‡Corolla tube glabrous.

||Style exceeding the calyx.

a. Glabrous or pubescent, but not glandular.

b. Flowers nodding. **P. cernua.**

bb. Flowers not nodding.

Glabrous or finely pubescent; leaves linear, 2-3 mm. wide. **P. longifolia.**

Roughish pubescent throughout; leaves thickish, 2-3 mm. wide. **P. Stansburyi**

Glabrous or somewhat roughish pubescent; leaves narrowly linear, 1-1.5 mm. wide. **P. linearifolia.**

aa More or less glandular, at least above.

b. About 5 dm. high. **P. tenuifolia**

bb. Less than 2 dm. high.

c. Corolla tube less than twice the length of the calyx

Viscid-pubescent above; leaves erect, narrowly linear, 1 mm. wide. **P. virida.**

Viscid-pubescent throughout; leaves linear, acuminate, erect, 2-4 mm. wide. **P. viscida**

Glandular-puberulent; leaves usually spreading, linear, acute or bluntish at apex, 1-2 mm. wide. **P. longifolia puberula.**

cc. Corolla tube twice the length of the calyx.

Roughish-pubescent throughout and glandular; leaves linear, thickish, 2-3 mm. wide. **P. Stansburyi.**

Leaves ovate, narrowly oblong or lanceolate. **P. Stansburyi brevifolia.**

ccc. Corolla tube 3-4 times the length of the calyx. **P. dolicantha.**

|| ||Style not exceeding the calyx.

Coarsely hirsute throughout; leaves thick and rigid, ovate to lanceolate, about 2 cm. long. P. hirsuta.

‡‡Corolla tube slightly pubescent.

Leaves ovate, thin and glabrous. P. adsurgens.

††Style not longer than the ovary or stigmas.

‡Ovules solitary in each cell.

||Upper leaves on flowering stems dilated at base.

Stems slender; leaves linear; flowers in lax corymbose clusters. P. speciosa.

Stems short and stout; leaves rigid, lanceolate; flowers in congested corymbose clusters. P. lanceolata.

|| ||Upper leaves on flowering stems not dilated at base.

1-3 dm. high; leaves lanceolate to linear, 3-5 cm. long. P. occidentalis.

5-10 cm. high; leaves oblong to oblong-linear, 1-4 cm. long. P. Woodhousei.

‡‡Ovules 2-3 in each cell.

Stems slender, usually simple; leaves narrow, 1-2 mm. wide. P. triovulata

Stems freely branched; leaves 3-4 mm. wide. P. nana.

2. ANNUALS; calyx teeth setaceous-tipped.

*Leaves of firm texture, nearly all opposite. P. aspera.

**Leaves thin, mostly alternate.

†Corolla tube pubescent, exceedingly the calyx.

Stems 1-4 dm. long; leaves broadest at base; corolla lobes about 1 cm. long. P. Drummondii.

Stems 5-10 cm. long; leaves rather narrow at base; corolla lobes about 6 mm. long. P. tenuis.

††Corolla tube glabrous, not exceeding the calyx. P. Roemeriana.

SYNOPSIS OF THE SPECIES.

***Pulvinate-caespitose or loosely caespitose perennials, often with erect annual stems, several cm. high; leaves approximated and often much imbricated, scarious-connate, the old ones marcescent; flowers sessile or short-peduncled, usually solitary; corolla tube somewhat hairy near the base within (the hairs wanting apparently in P. Hoodii); style more or less shorter than the corolla tube; ovules solitary in each cell.**

†Leaves more or less beset with woolly cobwebby hairs.

‡Leaves scale-like, ovate to lanceolate, much imbricated, rather densely arachnoid-lanate.

P. BRYOIDES Nutt. Pl. Gamb. in Journ. Acad. Nat. Sci. ser. 2, 1:153 (1848). Gray, Proc. Am. Acad. 8:253. Gray, Syn. Fl. 2:132.

From central Wyoming to Utah and Colorada. Type locality; "dividing ridge of the Rocky Mountains" in southern Wyoming (about lat. 42 degrees).

The typical forms have strictly 4-ranked scale-like leaves, but in luxuriant plants the leaves are much longer and the quadrifarious character entirely lost. In such forms it approaches very near to *P. muscoides* from which it can always be separated by its longer corolla tube.

Specimens examined: Wyoming; Henry Engelmann, "Mountains near Sweetwater" River, 1888; C. C. Parry, No. 230, High ground forming eastern rim of Green R. Basin, alt. 7000 ft.," 1873; B. C. Buffum, Cooper Creek, 1892; Aven Nelson, Nos. 67 (Laramie Hills, 1894), 1280 (Laramie Plains, 1895, the usual form with corolla lobes 3 mm. long), 3030a (Green River, 1897), 4313 (Laramie Hills, 1898) and 4618 (Carter, 1898, corolla lobes 6 mm. long): Southern Utah; A. L. Siler, No. 5, 1874: Colorado; T. S. Brandegee, Canon City, 1871, Sierra Sangre de Cristo Mts., 1874.

P. MUSCOIDES Nutt., Journ. Acad. Phila. 8:42, t. 6, fig. 2 (1834). Gray, Proc. Am. Acad. 8:253. Gray, Syn. Fl. 2:132.

Type locality; "Rocky Mountains at the sources of the Missouri River," western Montana.

Specimens examined: Montana; Mrs. C. H. Moore, Butte, 1883; F. D. Kelsey, "Very abundant in Deer Lodge Co. N. E. of Helena," 1891; W. T. Shaw, Deer Lodge, Bozeman, 1892.

‡‡Leaves less crowded, subulate, usually distinctly bisulcate, sparsely arachnoid-lanate, or with only a few hairs at base.

P. CANESCENS T. & G., Pacif. R. Rep. 2:122, t. 6 (1855).

Densely caespitose; lanate and somewhat canescent, at least when young; leaves subulate, pungent, somewhat granular-roughened, at length recurved-spreading, 6-10 mm. long; corolla white (tube "yellow"), the tube somewhat hairy at base within, twice the length of the calyx or nearly so, the lobes broadly obovate to rotund, usually entire, about 5 mm. long; style less than half the length of the corolla tube. Western Colorado to California. Type locality; "On the Cedar Mountains, south of Great Salt Lake," Utah.

Specimens examined: Utah; L. F. Ward, Mass Valley; M. E. Jones, No. 1698, Dog Valley, 1880, Terminus near Salt Lake, 1890, Summit, Owen's Valley, 1897: California; Mrs. C. C. Bruce, No. 2339, Warner Mts., 1898: Colorado; T. S. Brandegee, near Mt. Carbon, Elk Mts., 1881.

P. HOODII Rich. Frankl. Journ. Appx. t. 28 (1823).

Densely tufted and much branched from a somewhat woody root; sparsely lanate; leaves subulate, apiculate, with broader clasping bases, 4-10 mm. long; calyx 5-7 mm. long, the teeth like the leaves, the thickened central portion of the latter produced into strong ribs on the tube below; corolla white, the tube equalling or somewhat exceeding the calyx, the lobes obovate, entire or mucronate, about 5 mm. long. Flowering early in the spring, on the plains and foothills from Saskatchewan to Montana and Wyoming.

As Dr. Gray noted (Syn. Fl. 2:132), this seems to pass into *P. canescens*. It is apparent, however, that many forms, especially from Montana, have been referred to the latter which more properly belong to this species.

Specimens examined: Assiniboia; John Macoun, 1894: Montana; F. W. Anderson, Great Falls, 1885; J. W. Blankinship, Custer, 1890; R. S. Williams, No. 831, Great Falls, 1892; Mrs. J. J. Kinnedy, Missoula Co.: Wyoming; C. C. Parry, No. 231, "Upper Valley of Green River" (?).

P. HOODII GLABRATA n. var.

Glabrous except for a few lanate hairs on the calyx and at the base of the leaves; the latter granular-roughened and much greener than in the species; calyx teeth short; corolla tube slightly exceeding the calyx.

This variety takes the place of the species on the plains and foothills of Eastern Wyoming. On account of its green, glabrate leaves it has usually passed as *P. caespitosa*. It has however none of the pubescence characteristic of that alpine species while what little it has is like that of *P. Hoodii*.

Specimens examined: Wyoming; Dr. F. V. Hayden, "Deer Creek, 100 miles above Ft. Laramie," 1860; E. L. Greene, Cheyenne, 1872 (labeled P. Douglasii); Geo. Engelmann, Sherman, 1880; B. C. Buffum, Laramie, 1891; Aven Nelson, Laramie, 1892; J. Schneck, Orin Junction, 1893; Aven Nelson, Nos. 8 (1894, the type, in Herb. Univ. of Wyo.), 1892 (1896) and 2864 (1897), Laramie: Montana; J. M. Bates, Ft. Robinson, 1897: Colorado; North Park, 1897.

P. ANDICOLA (Britt.) n. sp.

P. Douglasii var. longifolia A.Gray, Proc. Am. Acad. 8:254 (1870). *P. Douglasii var. andicola* Britt. Mem. Torr. Club, 5:269 (1894).

Stems from a rhizome, usually erect, often branched at the surface of the ground and with opposite branches at the nodes, white, the bark exfoliating with age in thin shreds, 5-10 cm. high; sparsely lanate on the calyx and bases of the leaves, the stems granular-pubescent and somewhat glandular; leaves acerose or sublate or the larger plain, often somewhat bisulcate, pungent, 1-2 cm. long; flowers sessile or on peduncles 2 mm. long; calyx teeth as long as the tube, pungent; corolla white, the tube somewhat hairy near the base within, one and a half times the length of the calyx, the lobes broadly obovate, 5-7 mm. long; style about the length of the calyx. On the plains east of the Rocky Mountains, from Montana to Western Nebraska and Eastern Wyoming. The range given by Dr. Gray at place of original publication is, "east of the Rocky Mountains and in Utah."

In 1870 Dr. Gray described *P. Douglasii var longifolia*, giving it the following characters: "Ramis saepius erectis e rhizomate prostrato; foliis angustissime vel aceroso-linearibus lin. 5-8 longis minus fasciculatis." He gives its range as quoted above but it will be noticed that in the Synoptical Flora ("W. Nebraska to Oregon and N. E. California") he also includes some far western forms. I have seen no specimens from Oregon or California, which could be associated with any of those forms from east of the Rocky Mountains, which might be supposed to belong to this variety. Forms like Mr. Lemmon's No. 178 represent perhaps what Dr. Gray later (in 1878) included in *P. Douglasii longifolia*. Since those far western forms do not differ in any marked respect from the true Douglasii and are by far much nearer to it than to the forms east of the Rocky Mountains it is best to leave them with that species.

It is probable that Dr. Gray included some forms of the recent *P. austromontana* and especially the variety *prostrata* in his *P. Douglasii longifolia*, and indeed some Utah specimens are so labeled. Even if we knew exactly what Utah specimens Dr. Gray referred to, the name *andicola* could not properly be applied to them, for we have reason to believe that he based his variety principally upon plants from "east of the Rocky Mountains." The forms found in the last named region will therefore have to bear that name. Of these there are two which are quite distinct, namely, *P. multiflora* and the one described above. Since one of these has been definitely designated as *P. multiflora*, it is perfectly proper to apply the name *andicola* to the remaining one. We are also borne out in such disposition by the fact that the original characterization points to it rather than to *P. multiflora*. The latter has no true rhizomes, but prostrate persisting stems instead, and its annual stems are always one-flowered, while in *P. andicola* they bear several flowers. They differ also in the character of their pubescence, the latter being lanate, while that which often occurs on the peduncles and calyx of *P. multiflora* can be termed pubescent (in the restricted sense). In habitat they differ widely, *P. andicola* growing on the open plains, while *P. multiflora* is only found in the hills.

In some respects the species in question is allied to *P. Hoodii*. It has the same character of pubescence and the leaves bear striking resemblances. The habitat is the same and in Montana there occur some intermediate forms.

Specimens examined: Wyoming; B. A. Soulard, "On the Upper Platte river," 1845; Aven Nelson, No. 397, Fairbanks on the Platte, 1894; Nebraska; J. M. Bates, Valentine, 1895: North Dakota; Dr. F. V. Hayden, "common on high praries from Fort Pierre to bad lands," 1853: Montana; R. S. Williams, No. 117, Belt River, 1881; also a specimen by Hall and Harbour, No. 453, from Colorado, probably lat. 41 degrees, 1862.

††Leaves not beset with woolly cobwebby hairs.

‡Leaves ovate, oblong-linear or lance-linear, hispid-ciliate on the margins, especially near the base, rarely naked.

P. CONDENSATA (A. Gray) n. sp.

P. Hoodii var. A Gray, Enum, Pl. Parry. (298) in Sill. Journ. *P. caespitosa var. condensata* A. Gray, Proc. Am. Acad. 8: 254 (1870).

Densely pulvinate-tufted; leaves much imbricated, rigid, oblong-linear, apiculate, distinctly bisulcate, hispid-ciliate on the margins and slightly glandular, 5-6 mm. long; calyx as long as the leaves, the teeth oblong-linear, apiculate; corolla white, the tube twice the length of the calyx or less, somewhat hairy at the base within, the lobes rotund, 4-5 mm. long; style shorter than the calyx. At high altitudes in Colorado.

This should have specific rank. It is remarkably distinct from *P. caespitosa* which is less densely tufted and has larger leaves and flowers.

Specimens examined from Colorado: C. C. Parry, "From the headwaters of Clear Creek, and the alpine ridges lying east of Middle Park," 1861; Hall & Harbour, Lat. 39-41 degrees, 1862; Dr. Geo. Vasey on Powell's Colorado Exp. Exp., 1868; Hooker & Gray, No. 11.206, Sierra Blanca; F. S. Brandegee, No. 689, Sierra Sangre de Cristo Range, 1873 and 1874; H. N. Patterson, No. 101, Gray's Peak, alt. 11-14000 ft., 1885; Wm. Trelease, Leadville, 1886; Crandall & Cowen, Mts. above Como, alt. 12,000 ft., 1895; C. S. Crandall, Mts. above Boreas, 1897.

P. CONDENSATA HENDERSONI n. var.

Very viscid, the surface of the leaves covered with fine glandular-tipped hairs, much more densely so than in the species.

Type in Herb. Agr'l. Coll., Wash.; collected by L. F. Henderson, Mt. Adams, Washington, Aug. 10, 1892; also from the same locality by W. N. Suksdorf, 1884.

P. CAESPITOSA Nutt. Journ. Acad. Phila. 7:41 (1834).

Densely or somewhat loosely caespitose, often with long, prostrate stems; leaves oblong-linear or lanceolate, apiculate, 8-14 mm. long, 1-2 mm. wide, usually plane, the somewhat cartilaginous margins hispid-ciliate or naked, surface glabrous or with short scattered glandular-tipped hairs; flowers sessile or subsessile (peduncles rarely 2 mm. long); calyx more or less hispid-ciliate and usually with some short glandular-tipped hairs, the teeth the length of the tube, lanceolate or narrowly so, pungent; corolla white or light blue, the tube slightly hairy at base within, about three times the length of the calyx teeth, the lobes broadly obovate, 5-7 mm. long. In the mountains from New Mexico to Montana. Type locality; "Flat-Head river, on the sides of dry hills."

Specimens examined: New Mexico; N. K. Berg, Franklin, "timber line," 1897: Colorado; A. Eastwood, La Plata Mts., 1892; Baker, Earle and Tracy, No. 249, Mt. Hesperus, No. 635, Little Kate Basin, La Plata Mts., alt. 12,000 ft., 1898: Utah; M. E. Jones, No. 594c, Marysvale, 1894: Wyoming; Aven Nelson. No. 1827 (1895), Elias Nelson, No. 5216 (1898), La Plata Mines, alt. 12,000 ft.: Montana; J. B. Allebaugh, Wisconsin Creek, 1892; Emma J. Ware, Deer Lodge Co. (a narrow-leaved, very glandular form).

P. CAESPITOSA RIGIDA (Benth.) A. Gray. *P. rigida* Benth. in DC. Prodr. 9:306 (1845). *P. caespitosa var. rigida* A. Gray, Proc. Am. Acad. 8:254 (1870).

I have seen no specimens of this variety. It was originally described from the Blue Mountains of Oregon (in montibus caeruleis Americae boreali-occid.), and is perhaps confined to the mountains of the Pacific coast states. Watson reports it from the Clover mountains of Nevada (Bot. King. 260). Since specimens are not at hand I retain this as a variety. An examination of good material might prove it to be more properly a species.

P. COVILLEI n. sp.

Depressed-caespitose; leaves ovate, oblong or linear-oblong, apiculate, 3-5 mm. long, hispid-ciliate on the thickened cartilaginous somewhat inflexed margin as also the upper surface, a little glandular and granular-roughened, central portion thickened and with a groove on either side; flowers sessile; calyx 5-7 mm. long, hispid-ciliate and glandular, teeth thick, short or as long as the tube, the central portion produced into thick cartilaginous ribs on the calyx tube below; corolla white, the tube quite hairy at base within, more than twice the length of the calyx, the lobes broadly obovate to rotund, 4 mm. long; style short, less than half the length of the corolla tube.

This cannot be referred to *P. caespitosa*. The much shorter, broader leaves, and the grayish color of the whole plant, distinguish it from that species. In leaf characters it seems to be allied to *P. albomarginata.* That species, however, has plane leaves and the flowers are raised above the ground and, at least in the variety *minor*, peduncled.

I take great pleasure in dedicating this species to Frederick Coville, who, together with Frederick Funston, collected it on the Death Valley Expedition. Type in Herb. California Academy of Sciences; No. 1801, Black Canon, White Mountains, Mono Co., California, 1891.

P. ALBOMARGINATA Jones, Zoe 4:367 (1894).

Specimens of this species are not at hand. It is characterized by its short, broad cartilaginous marginal leaves and exceedingly glandular calyx. Type locality; "East face of Mt. Helena, Montana."

P. ALBOMARGINATA MINOR Jones, l. c.

A specimen collected at Helena, Montana, by F. D. Kelsey, 1890, I take to be of this variety. It differs from the species in the absence of flowering stems, in its smaller leaves and shorter calyx. The flowers are on peduncles about 6 mm. long.

‡‡Leaves not hispid-ciliate on the margin.

||Sparsely lanate- or hirsute-ciliate on the calyx and usually at the base of the leaves, otherwise glabrous or with short fine glandular-tipped hairs on the leaves and stems; leaves acerose (at least those fascicled in the axils).

P. DIFFUSA Benth. Pl. Hartw. 325 (1849). *P. Douglasii var. diffusa* A. Gray, Proc. Am. Acad. 8:254 (1870).

Loosely caespitose-spreading, with prostrate loosely branched stems, the annual ones of 1-4 nodes, one-flowered, 2-3 cm. long; leaves 6-12 mm. long, a pair of spreading oblong-linear (2 mm. wide or less) ones with narrow thin white margin and somewhat narrowed base at each node, with acerose, apiculate ones in their axils; flowers sessile or subsessile; calyx sparsely lanate-ciliate or sometimes glabrous, the teeth the length of the tube; corolla white, the tube somewhat hairy at base within, twice the length of the calyx or less, the lobes obovate or broadly so, entire or erose, 6-9 mm. long; style usually nearly equalling the corolla tube. Oregon to British Columbia.

Dr. Gray made this a variety of *P. Douglasii* but that does not seem satisfactory, for it exhibits some very good distinctions from that. It is much laxer in growth, the internodes being longer, and has broader and shorter leaves and longer style. It also grows in much moister places and is of a more northern distribution.

Specimens examined: Washington; L. F. Henderson, Mt. Adams, 1892, "Alpine slopes, Olympic Mts.," 1890; Lake & Hull, No. 595, Horse-shoe basin, near Skagit Pass, 1892; C. V. Piper, Olympic Mts., Mt. Rainier, 1895; O. D. Allen, No. 265, 1896: Oregon; Elihu Hall, No. 414, 1871; L. F. Henderson, Summit of Ashland Butte, 1886: British Columbia; John Macoun, Mt. Arrowsmith on Vancouver Island, 1887.

P. DOUGLASII Hook. Fl. Bor. Amer. 2:73 (1838).

Caespitose, often loosely so with much-branched prostrate stems from a more or less woody root; sparsely lanate-ciliate on the calyx, base of leaves and stems or nearly glabrous; leaves acerose, pungent or apiculate, 5-15 mm. long; flowers sessile or subsessile, solitary, rarely the annual stems 3-flowered; calyx teeth the length of the tube, acerose-subulate; corolla white or light blue, the tube somewhat hairy at base within, a little less than twice the length of the calyx, the lobes obovate to rotund, 5-7 mm. long; style half the length of the corolla tube or less. Common in Oregon and California, also in Idaho, Nevada, and southwestern Colorado. Type locality; "N. W. America: common on the Limestone range of the Blue Mountains (Oregon), and on the Rocky Mountains, near the confines of snow."

Of all the forms, merged into this species by Dr. Gray, the one so common in Oregon and California is here taken as the true *P. Douglasii*. The leaves of this are not noticeably rigid but often rather weak and spreading. They are either strictly acerose or somewhat plane and often with inflexed but not at all thickened margins. As a rule they are not grooved, at least not so strongly or distinctly as in *P. condensata.* In the specimens examined there is some variation especially in habit but not marked enough to justify any further seggregation. The Oregon specimens have a much softer pubescence and approach much nearer to *P. diffusa* than some of those from California. The latter, of which Coville and Funston's No. 1830 and Lemmon's 178 are representatives, exhibit a coarser, somewhat hirsute pubescence and the annual stems are often 3-flowered.

Specimens examined: Washington; Mrs. W. L. Steinweg, Cascade Mts., Yakima Co., 1894: Oregon; Dr. J. H. Bartholf, Camp Harney, 1875; Mrs. R. M. Austin, Southeastern Oregon (labeled P. Douglasii longifolia), Quartz Valley (labeled P. caespitosa), 1893; C. V. Piper, Powder River Mts., 1896; L. F. Henderson, Mt. Hood, 1896 (labeled P. Douglasii diffusa): Idaho; A. Isabel Mulford, near Ketchum, 1892: California; J. G. Lemmon, Nos. 81, Sierra Valley, and 178, Sierra Co. 1874 (labeled P. Douglasii longifolia); Geo. Engelmann, Mt. Shasta, 1880; M. E. Jones, No. 2470, Soda Springs, Nevada Co. 1881; Mrs. Austin, Davis Creek, 1892; Geo. Hansen, No. 499, Amador Co., 1892 and 1895 (labeled P. caespitosa); C. A. P——, Tulore Co., 1896; Mrs. C. L. Proctor, Mt. Shasta, 1896; H. E. Brown, No. 362 1-2, Mt. Shasta, 1897 (labeled P. caespiosa); Alice Eastwood, Summit, Placer Co., 1898: Nevada; M. E. Jones, Carson City, 1897: Southwestern Colorado; Alice Eastwood, Mancos, 1891.

P. PIPERI n. sp.

Many-stemmed and much branched from a woody root, the woody persistent stems erect or ascending, 10-15 cm. high, these often arising from horizontal rhizomes; the whole plant sparsely covered with short, fine, glandular-tipped hairs throughout, the bases of the leaves and the calyx hirsute-ciliate; leaves spreading, acerose, pungent, 5-10 mm. long; flowers solitary, usually on peduncles 2 mm. long; calyx teeth acerose, pungent; corolla white or light blue, the tube somewhat hairy at base within, one and a half times to twice the length of the calyx, the lobes obovate to cuneate-obovate, 6-9 mm. long; style about half the length of the corolla tube.

Type in Herb. Agr'l. Coll., Wash; collected by C. V. Piper at Spokane, Washington, May 16, 1896; from the same locality by A. A. and E. Gertrude Heller, April 21, 1896. A specimen by W. C. Cusick, No. 1601, from Easetrn Oregon (1897) is also referred here.

|| ||Pubescent or canescent-pubescent, never glandular, often entirely glabrous; leaves plane or subulate from a broader base.

P. AUSTROMONTANA Coville, Cont. Nat. Herb. 4:151 (1893).

Southern Utah, northern Arizona and southern California. Type locality, "Beaverdam Mountains, Utah."

This excellent species is characterized by its canescent pubescence and by the replicate sinuses of the calyx. It is a near relative of *P. Douglasii* which it resembles in habit, but differs from that in the above named characters and in its several flowered annual stems. The leaves are acerose from a broader base and usually somewhat bisulcate or often nearly plane. The corolla tube is rather noticeably hairy near its base within.

Specimens examined: Southern Utah; C. C. Parry, Mts. near St. George, 1874; A. H. Siler, No. 16, Mts. near Osmer, 1874; Dr. E. Palmer, No. 307, "S. Utah, N. Arizona," 1877; M. E. Jones, No. 5122, Diamond Valley, 1894: California; C. R. Orcutt, No. 885, Topo Canon, 1883; S. B. Parish, Nos. 1839 (1886) and 2955 (1894) San Bernardino Mts.

P. AUSTROMONTANA PROSTRATA n. var.

Loosely caespitose-spreading, with long prostrate laxly-branched stems which are often 3 dm. long; leaves usually plane, 20-25 mm. long; flowers large, the corolla tube 2 cm. long, the lobes erose, 1 cm. long.

It has the canescent pubescence and the replicate calyx sinuses of the species, but its more diffuse habit and its longer planer leaves readily distinguish it.

Type in Herb. Univ. of Wyo.; collected by M. E. Jones, No. 5163 y & z, at Silver Reef, Utah, May 4, 1894.

P. MULTIFLORA Aven Nelson, Bull. Torr. Bot. Club, 25:278 (1898). *P. Douglasii var. longifolia.* A. Gray, Proc. Am. Acad. 8:254 (1870), in part.

In the foothills east of the Rocky Mountains, from Montana to Colorado. Type locality; Laramie Hills, Albany Co., Wyoming.

This species is very distinct and need not be confused with anything else. Its simple, erect, one-flowered annual stems with comparatively long internodes and little if at all fasicled plane leaves separate it from all related species. The plant is often glabrous throughout, but generally the calyx and peduncles are pubescent. The same hairiness in the corolla tube observed elsewhere in this group also occurs here.

Specimens examined: Montana; J. H. Flodman, Spanish Basin, 1896; P. Koch, Lake Plateau, 1897: Wyoming; Dr. F. V. Hayden, "Summit of Wind River Mts.," 1860; C. C. Parry, "N. W. Wyo.," 1873; J. W. Blankinship, Big Horn Mts., 1890; B. C. Buffum, Upper Laramie River, 1891; Aven Nelson, Nos. 182, 1894, and 3175 (type), 1897, Laramie Hills, No. 813, Union Pass Hills, 1894; Elias Nelson, No. 4864, Freezeout Hills, 1898: Colorado; W. A. Henry, Gregory Canon, 1875; J. J. McFarland, Boulder Co., 1881; Alice Eastwood, Durango, 1891; C. S. Crandall, Mountans of Northern Colo., 1890, Rist Canon, 1891, Platte Canon, 1894; C. F. Baker, Ft. Collins, 1896.

P. MULTIFLORA DEPRESSA n. var.

Depressed caespitose, scarcely rising above the ground; leaves 1 cm. long, rarely 2 cm.; flowers mostly subsessile, the corolla lobes 6-7 mm. long (in the species 8-9 mm).

I thus designate a form from the Red Desert of South-Western Wyoming. Type in Herb. Univ. of Wyo.

Specimens examined from Wyoming: Dr. F. V. Hayden, Kamas Prairie and head of Wind River Valley, alt. 6500, 1860; Aven Nelson, Nos. 3084 (type), Point of Rocks (1897), 4677, Kemmerer, and 4536, Cokeville (1898).

|| || ||Pubescent or hirsute, often glandular, not infrequently entirely glabrous; leaves plane, lance-linear.

P. KELSEYI Britt. Bull. Torr. Bot. Club, 19: 225 (1892).
From Montana and the Dakotas to Southern Wyoming.

This varies from entirely glabrous to densely hirsute, and some specimens from southern Wyoming are glandular throughout; but, since this form agrees in every other respect, and since some Montana plants also exhibit a tendency to be glandular, it seems best to refer it to this species. The peduncles and young stems are narrowly wing-angled, a character which is never so prominent in any other species. The membranous sinuses of the calyx are very narrow, and show no indications of becoming replicate.

Specimens examined: Montana; F. D. Kelsey, Helena, 1890, Coeur d'Alene, 1891; Mrs. L. A. Fitch, Twin Bridges, 1892, Madison Co.; J. H. Flodman, Little Belt Mts., 1896: South Dakota; Alice D. Pratt, Piedmont, 1895; J. M. Bates, No. 1152, Hot Springs, 1896: Wyoming; J. M. Bates, Newcastle, 1896; Elias Nelson, No. 4336, Cooper Creek, Albany Co., 1898 (the glandular form).

P. GLADIFORMIS (Jones) n. sp.
P. longifolia var. gladiformis Jones. Proc. Cal. Acad. Sci. Ser. 2, 5:711 (1895).

Loosely caespitose with prostrate spreading stems; softly pubescent and slightly glandular throughout; leaves rather thick and rigid, with prominent midribs and slightly revolute margins, lance-linear, pungent, 15-20 mm. long, about 2 mm, wide; flowers sessile or subsessile; calyx with sinuses distinctly but only moderately replicate, the teeth slightly longer than the tube, pungent; corolla white, the tube pubescent (on the exterior) and near the base within rather densely so, twice the length of the calyx, the lobes cunate-obovate, entire, 7 mm. long; style less than half the length of the corolla tube. Utah. Type locality; "Cedar City," Utah.

The nearest relative of this is *P. Kelseyi* with which it agrees in habit and leaves. It is readily distinguished from that by its more sessile flowers, pubescent corolla tube and by the character of its calyx. Mr. Jones referred it to *P. longifolia*. The replication of the calyx sinuses would indeed suggest such relationship, yet it has neither the long style nor the habit which is characteristic of that group. On the other hand its chief characters allies it to *P. Kelseyi*, and were it not a good species it would have to become a variety of the same. The above description has been drawn from some specimens of Mr. Jones' type number, 5208c, collected by him at Cedar City, Utah, May 8, 1894.

**Suffrutescent or nearly herbaceous perennials, loosely tufted and many-stemmed; leaves generally distant, very little if at all fascicled in the axils, as a rule not marcescent on the stems below; flowers in corymbose cymes; calyx with white-membranous intercostal sinuses which are usually replicate and often produced into salient angles, the teeth equalling or shorter than the tube, apiculate or pungent; corolla tube more or less hairy at base within; style long and slender equalling the corolla tube or at least longer than the ovary or stigmas; ovules one or two in each cell.

†Corolla tube glabrous.

‡Style exceeding the calyx.

||Corolla tube twice the length of the calyx or less.

a. Flowers nodding.

P. CERNUA n. sp.

Suffrutescent at base and many-stemmed, 8 cm. high, the lower part of the stems purple; glabrous throughout or the stems puberulent below; leaves linear, spreading, 2-3 cm. long, less than 2 mm. wide; flowers on slender pedicels (about 1 cm. long), inclined to be nodding; calyx with somewhat replicate sinuses, the teeth half the length of the tube; corolla white or tinged with purple, the tube twice the length of the calyx, the lobes obovate, entire or somewhat erose, 7-8 mm. long; ovules solitary in each cell.

Type in Herb. Univ. of Wyo.; collected by C. S. Crandall at Cimarron, Montrose Co., Colo., May 18,1898.

aa. Flowers not nodding.

P. LINEARIFOLIA (Hook.) A. Gray. *P. speciosa* Lindl. Bot. Reg. t. 1351 (1828). *P. speciosa var. linearifolia*

Hook. Kew. Journ. Bot. 3:289 (1851). P. linearifolia A. Gray, Syn. Fl. 2:133 (1878).

Loosely tufted, more or less suffrutescent with erect or assurgent stems; entirely glabrous or roughish pubescent; leaves narrowly linear, pungent, 2-5 cm. long, 1-2 mm. wide; flowers as a rule long-pedicelled; calyx more or less angled by the replication of the sinuses, often strongly so, the teeth somewhat acerose, pungent, about the length of the tube, corolla white, blue or rose-color, the tube less than twice the length of the calyx, the lobes obovate or narrowly so, usually entire, 8-12 mm. long; ovules 1or 2 in each cell. On the interior plains of the Columbia River and its tributaries in Western Idaho, Washington and Northern Oregon. Type lacality; "N. W. America, Plains of the Columbia."

This species presents considerable variation in habit and degree of pubescence. Forms like C. V. Piper's specimens from Almota, Washington, have usually passed as *P. linearifolia* among recent collectors, while glabrous forms have been labeled *P. longifolia*. It is not readily distinguished from *P. longifolia*. which displaces it in the Rocky Mountain region but is however as a rule separated from that by its shorter and narrower leaves.

Specimens examined: Idaho; J. H. Sandberg, No. 25, "Common on hillsides, valley of Clearwater River, Nez Perces County," 1892. (This form is erect in habit, many-stemmed from the base and glabrous or only slightly pubescent, with calyx moderately angled and two ovules in each cell. It seems to fit the description of P. speciosa Lindl. in Hook. Fl. Bor. Am. 2:72 as well as any specimens seen); L. F. Henderson, Lewiston, 1894; A. A. & E. Gertrude Heller, Lewiston, 1896 (glabrous, leaves even 5 cm. long; calyx 15 mm. long, ovules 2 in each cell): Washington; Chas. A. Ramm, Spokane, Co., 1883 (slender form); L. F. Henderson, Sprague, 1892, Yakima, 1892 (corolla lobes obovate, 7 mm. long); W. R. Hull, Pataha, 1892; E. R. Lake, Wawawai, 1892; C. V. Piper, Almota, 1893 (very pubescent, persisting stems prostrate, the annual ones erect or assurgent, corolla lobes narrowly obovate, 10-12 mm. long, ovules usually 2 in each cell); C. V. Piper, Wawawai, 1893 (pubescent, corolla lobes 15 mm. long, acuminate-acute); Mrs. W. L. Steinweg, North Yakima, 1894; H. H. Hindshaw, Pasco, 1896; C. V.

Piper, North Yakima, 1898 (a low form with weak stems and green spreading leaves, about 2 cm. long, glabrous, calyx strongly angled, corolla lobes mostly cuneate-oblong, 6-9 mm. long, ovules 2 in each cell): Oregon; Rev. M. Spalding, Clearwater, No. 11,963.

P. VIRIDA n. sp.

Rather woody at base, the annual stems numerous erect and leafy, 6-10 cm high, rarely 15 cm; glabrous below, viscid-pubescent above and with a few longer crisp hairs on the calyx; leaves noticeably green, linear, pungent, 2-3 cm. long, 1 mm. wide; flowers usually in contracted corymbose cymes, with rather stout pedicels; calyx moderately angled by the replication of the sinuses, the teeth the length of the tube and pungent; corolla light blue, the tube somewhat exceeding the calyx, the lobes cuneate-obovate, emarginate or nearly obcordate, 6-7 mm. long; ovules solitary in each cell.

Characterized by its viscid pubescence and unusually green leaves. Type in Herb. Agr'l. Coll. Wash.; collected by C. V. Piper, Ellenburg, Washington, May 20, 1897; also, from Idaho, by A. Isabel Mulford, Boise flats, 1892.

P. VISCIDA n. sp.

Stems erect, 10-15 cm. high; viscid pubescent throughout, the pedicels and calyx densely so, the latter also somewhat hirsute; leaves noticeably green, linear to narrowly lanceolate, pungent, 2-4 cm. long, 2-4 mm. wide; flowers on pedicels 1-2 cm. long; calyx 13 mm. long, with sinuses only slightly replicate (in type apparently not at all), the teeth about the length of the tube, green, apiculate; corolla rose-color (?), the tube slightly exceeding the calyx, the lobes obovate or narrower, finely erose, 7 mm. long; ovules solitary in each cell.

I confidently propose this as a new species. Its viscid pubescence and much broader leaves at once distinguish it from *P. longifolia* and *P. linearifolia*. It has been labeled *P. longifolia var Stansburyi*, with which it cannot be associated, its relationship being rather with *P. longifolia*. Type in Herb. Agr'l. Coll., Wash.

Specimens examined: Washington; Thos. Howell, No. 1380, Klickitat Valley, 1881; C. V. Piper, Blue Mts. Columbia Co., June 15, 1896 (type): California; H. N. Bolander.

P. LONGIFOLIA Nutt. Journ. Acad. Phila. 7:41 (1834).
P. speciosa var. b Hook. Fl. Bor. Am. 2:72 (1838).
P. humilis Dougl. Benth. in DC. Prodr. 9:306 (1845).

Usually erect in habit, 10-25 cm. high; finely pubescent or glabrous; leaves linear, with prominent midveins and somewhat thickened cartilaginous margins, 3-6 cm. long, 2-3 mm. wide; flowers on pedicels 1-3 cm. long; calyx with slightly replicate sinuses; corolla white, the tube somewhat exceeding the calyx, the lobes obovate or cuneate-obovate, entire, emarginate or erose, 8-10 mm. long; ovules generally solitary in each cell. Along the western side of the Rocky Mountains from Montana to Colorado and Utah, also in Oregon (Blue Mountains) and Washington.

Hooker gives as the range of his *P. speciosa var b*, "Subalpine range of the Rocky Mountains near perpetual snow, and on the Blue Mountains, N. W. Am.," which indeed seems to be nearly the range of this species for although it belongs principally to the Rocky Mountain region a low far western form must also be referred here. *P. humilis*, a form growing "in aridis sabulosis ad. flum. Columbia Americae boreali-occid.," is *P. speciosa var b*, Hook. in part. It is probable that Douglas based his *P. humilis* on specimens similar to those cited below from Oregon and Washington. There seems to be nothing however which would warrant its separation from *P. longifolia.*

On the whole it is a little stouter in habit and with shorter pedicels than *P. linearifolia*. Its pubescence is finer and the ovules are seemingly always solitary in each cell. To the south it gradually passes into *P. Stansburyi*, yet from the typical forms of that it is readily distinguished.

Specimens examined: Montana; F. V. Hayden, Madison River, 1860; W. F. Shaw, Bozeman, 1892; Mrs. C. H. Moore, Butte, 1893; Mrs. Hodgman, Gallatin Co.: Wyoming; F. V. Hayden, (a series of

collections), Jackson's Hole, 1860; Aven Nelson, No. 4629, Cokeville, 1898: Colorado; J. H. Cowan, Leroux Creek, Delta Co., 1892; C. S. Crandall, Palisades, Mesa Co., 1898: Utah; M. E. Jones, Salt Lake City, 1880: Washington; Kirk Whited, Weuatchee, 1896: Oregon; Rev. M. Spalding.

P. LONGIFOLIA PUBERULA n. var.

Low, 1 dm. high or less, stems erect or ascending; more or less glandular-puberulent, very densely so on the pedicels and calyx, nearly destitute of roughish hairs; leaves usually spreading, linear, bluntish at tip or apiculate, 2-4 cm. long, 1-2.5 mm. wide; replication of the calyx sinuses very slight and inconspicuous; corolla light blue or lilac, the lobes obovate or cunate-obovate, retuse or blunt, 7-12, mm. long; ovules solitary in each cell.

I thus designate what seems to be quite a distinct form, which, were it not for its gradual gradation into *P. longifolia*, would be a good species. Type, No. 4544, in Herb. Univ. of Wyo.; collected by Aven Nelson at Evanston, Wyo., June 5, 1898; also No. 2964, from same locality, 1897.

P. STANSBURYI (Torr.) Heller, Bull. Torr. Bot. Club. 24:478 (1897). *P. speciosa var.* (?) *Stansburyi* Torr. Bot. Mex. Bound. 145 (1859). *P. longifolia var. Stansburyi* A. Gray. Proc. Am. Acad. 8:255 (1870).

Stems several from a ligneous base, rather stout, usually simple below, cymosely branched above into leafy-bracted corymbs, about 1 dm. high; pubescent throughout, roughly so above, the pedicels and calyx usually glandular; leaves thick, usually recurved-spreading, linear or linear-lanceolate, apiculate, 20-35 mm. long, 2-3 mm. wide; flowers on pedicels 5-15 mm. long; calyx 1 cm. long, the sinuses more or less replicate, the teeth apiculate or somewhat cuspidate attenuate, as long as the tube; corolla pink or rose-color, the tube fully twice the length of the calyx, the lobes cuneate-obovate, erose, emarginate or retuse, 7-8 mm. long; ovules usually one in each cell. Southern California to New Mexico, Southern Colorado and Utah. Type locality; Organ and San Luis Mountains, New Mexico.

Specimens examined: California; Coville and Funston, No. 744, Panamint Mts., 1891: Utah; Henry Englemann, Salt Lake City, 1872; M. E. Jones, Cisco, 1890, No. 5198, Cedar City, 1894; Arizona; E. Palmer, Cottonwood Creek, 1876; H. H. Rusby, 1883; M. E. Jones, 1884; C. C. Pringle, Santa Rita Mts., 1884; C. G. Pringle, Santa Rita Mts., 1885: New Mexico; E. O. Wooton, No. 158, Organ Mts:, 1892; A. A and E. Gertrude Heller, Barranca, 1897: Colorado; T. S. Brandegee, Devil's Canon, 1878; Alice Eastwood, Crested Butte, 1890.

P. STANSBURYI BREVIFOLIA (A. Gray) n. com.

P. longifolia var. Stansburyi A. Gray forma brevifolia A. Gray, Proc. Am. Acad. 8:255 (1870). *P. longifolia var. Stansburyi A. Gray subvar. brevifolia* A. Gray, Wats. in Bot. King Surv. 261 (1871). *P. longifolia var. brevifolia* A. Gray, Syn. Fl. 2:133 (1878).

Low, 5-6 cm. high; leaves short and broad, ovate to lanceolate or narrowly oblong, apiculate-acute, 6-15 mm. long, 3-4 mm. wide; pubescent throughout, the pedicels and calyx glandular.

Specimens examined: Nevada; M. E. Jones, Reno, 1897: Northern Arizona; E. Palmer, No. 306, 1877.

Corolla tube tubular-funnelform, nearly twice the length of the calyx.

P. TENUIFOLIA n. sp.

Erect suffruticose perennial, 5 dm. high or more, the annual stems 25-30 cm. long, the internodes often 6 cm. long; glabrous below, sparsely glandular-pubescent above, the calyx hirsute-ciliate; leaves linear-attenuate, 25-35 mm. long; flowers in lax irregular corymbose cymes, the pedicels 1 cm. long; calyx 6-10 mm. long, with sinuses barely if at all replicate, the teeth lanceolate-attenuate, shorter or even longer than the tube; corolla white, the tube twice as broad at throat as at base, nearly twice the length of the calyx, the lobes oblong or cuneate-oblong, erose, 8 mm. long; ovules solitary in each cell.

The type of this excellent species is in Herb. Mo. Bot.

Garden; colected by C. G. Pringle in the "Rocky canyons of the Santa Catilina Mts.," Arizona, April 11, 1881. It has also been collected by J. W. Toumey in the same locality and by W. T. Parish at Lowell, Ariz.

|| || ||Corolla tube 3 to 4 times the length of the calyx.

P. DOLICANTHA A. Gray, Proc. Am. Acad. 22:310 (1887).

Herbaceous to the ground, about 1 dm. high, the stems branched, the branches opposite below and equalling the main stem; sparsely pubescent more or less throughout with short glandular-tipped hairs, noticeably so on the pedicels and calyx; leaves thick and with prominent midribs, alternate above, linear to lanceolate, the larger ones with occasional retrose teeth, those on the main stems 30-50 mm. long, 5-8 mm. wide, those on the branches 25-35 mm. long, 2-4 mm. wide; flowers scattered, on stout pedicels, the latter 10-25 mm. long; calyx with sinuses barely if at all replicate, the teeth slightly shorter than the tube; corolla rose-color (?), the tube 3-4 times the length of the calyx, the lobes obovate, entire, 9-10 mm. long; ovules solitary in each cell. San Bernardino Mountains of southeastern California and Pahranagat Mountains of southeastern Nevada.

Specimens examined from southeastern California; S. B. Parish, Nos. 1880, 1838 (1886) and 2956 (1894), San Bernardino Mts.

‡‡Style not exceeding the calyx.

P. HIRSUTA n. sp.

Very woody at base with stout annual stems, the latter about 1 dm. high; coarsely hirsute throughout with long jointed hairs; leaves thick and rigid with granular-roughened and often a little revolute margins, ovate to lanceolate, on sterile shoots linear, about 2 cm. long; flowers subsessile or short-pediceled; calyx with very narrow white-membranous sinuses not replicate, the teeth rigid and somewhat bisulcate, lanceolate or linear, apiculate; corolla tube exceeding the calyx; corolla lobes broadly cuneate-obovate, entire, about 8 mm. long; style 4 mm. long, shorter than the calyx; ovules solitary in each cell.

The short style and hirsute pubescence distinguish this from any of the other species of this group. Its relationship is apparently with *P. Stansburyi var brevifolia.* The type is in the Herb. Mo. Bot. Garden; collected by E. L. Greene, No. 719, near Yreka, Siskiyou County, California, May 26, 1876.

††Corolla tube slightly pubescent.

P. ADSURGENS Torr. Gray, Proc. Am. Acad. 8:256 (1870), Gray, Syn. Fl. 2:133.

Oregon and Northern California. Type locality; "Canon Pass, Oregon."

Specimens examined: Oregon; Wm. C. Cusick, Linn Co.; Th. Howell, Coast Mts. near Roseburg, 1887; L. F. Henderson, Crow-Creek Mts., Glendale, 1887; Miss Chandler, Glenbrook, 1896: California; Mrs. Stringer, Seiad Valley, Siskiyou Co., 1897.

***Suffrutescent or nearly herbaceous perennials, with more or less distant linear or lanceolate leaves; flowers in cymose clusters or scattered; calyx with white membranous sinuses not replicate or only slightly so, rarely produced into salient angles; corolla tube somewhat hairy near the base within; slightly exceeding the calyx, rarely twice its length; style very short, not longer than the ovary or stigmas; ovules 1 to 3 in each cell.

†Ovules solitary in each cell; corolla lobes usually obcordate or retuse.

P. LANCEOLATA n. sp.

Stems short and stout, from a woody base, 10-15 cm. high; finely glandular-pubescent throughout, pedicels and calyx viscid; leaves thick and rigid, with prominent midribs and cartilaginous margins, lanceolate, the upper dilated at base, those on sterile shoots linear, 2-4 cm. long; flowers in congested, leafy-bracted corymbose clusters; corolla white, the tube slightly exceeding the calyx, the lobes obcordate or only retuse, about 8 mm. long; ovules solitary in each cell. Washington.

A good species, characterized by its broad, thick, rigid leaves, its viscid pubescence and very close flower clusters.

Type in Herb. Agr'l. Coll. Wash., collected by C. V. Piper, Ellenburg, Wash. 1897; also, by L. F. Henderson, Clement's Mt., Yakima Co., Wash., 1897.

P. SPECIOSA Pursh, Fl. Am. Sept. 1:149 (1814).

Shrubby at base, erect in habit, 5-10 dm. high, profusely flowered; glandular-puberulent or viscid above, usually glabrous below; leaves with more or less prominent cartilaginous margins and the leaf surface nitidous under a lens, linear, 4-7 cm. long, those on the sterile shoots about 2 mm. wide, those on the flowering stems broader and the upper linear-attenuate from a dilated base; flowers in lax corymbose clusters; corolla rose-color or white, the tube a little exceeding the calyx, the lobes obcordate, 8-14 mm. long; ovules solitary in each cell. Western Idaho and Washington. Type locality; "On the plains of the Columbia."

Specimens examined: Idaho; L. F. Henderson, Juliaetta, Latah Co., 1895; A. A. & E. Gertrude Heller, Nez Perces Co., 1896: Washington; C. V. Piper, Almota, 1893, Pullman, 1893 and 1894; Sandberg and Leiberg, Spokane, 1893; A. D. E. Elmer, Nos. 148 and 839 Pullman, 1896 and 1897.

P. SPECIOSA SABINI (Dougl.) A. Gray. *P. speciosa Lindl. var. g* Hook. Fl. Bor. Amer. 2:72 (1838). *P. sabini* Dougl. in Hook. Kew. Journ. Bot. 3:289 (1851). P. speciosa Pursh. var. Sabini A. Gray, Syn. Fl. 2:134 (1878).

Like the species but corolla lobes entire or nearly so. Range of the species.

Specimens examined: Washington; W. R. Hull, Pullman, 1892; C. V. Piper, Almota, 1893: Idaho; L. F. Henderson, "Sunny Bluffs near Juliaetta," 1895.

P. OCCIDENTALIS Durand, in Pacif. R. Rep. 4:125 (1856). *P. speciosa var. latifolia* Hook. Kew. Journ. Bot. 3:289 (1851). *P. divaricata* Durand, Pl. Pratt. in Journ. Acad. Phila. ser. 2, 3 (1855).

More or less shrubby at base, 1-3 dm. high, stems usually assurgent, often erect; glandular-puberulent or somewhat viscid above, often entirely glabrous; leaves lanceolate to linear, 3-5 cm. long, 4-9 mm. wide, those on sterile shoots linear, about 4 mm. wide, flowers in leafy-bracted clusters; corolla white or rose-color, the tube somewhat exceeding the calyx, the lobes obcordate, often deeply so, 7-12 mm. long; ovules solitary in each cell. California to Washington. Type locality; "Hill-sides, near Duffield's Ranch," California.

This is intermediate between *P. Woodhousei* and *P. speciosa*, differing from the latter in its broader leaves and leafy-bracted flower clusters. It is very common in California, and extends northwards to Washington, while *P. speciosa* seems to be confined to the region drained by the Columbia River.

Specimens examined: California; W. I. Fisher, No. 585, San Diego, 1876; E. L. Greene, No. 767, Yreka, Siskiyou Co., 1876; G. Eisen, No. 585, Fresco Co., 1877; Mrs. R. M. Austin, Plumas Co., 1877; J. G. Lemmon, No. 37, Mts., Plumas Co., 1879; T. S. Brandegee, Amador Co., 1886; Geo. Hanson, Nos. 120 and 910 Amador Co., 1891, 1893 and 1895; Alice Eastwood, Sequoia Mills, Fresco Co., 1894; H. E. Brown, No. 316, Sisson, Siskiyou Co., 1897; M. E. Jones, Diamond Mt., 1897; G. P. Rixford, Eldorado, 1898: Washington; T. S. Brandegee, No. 14,187, Yakima region of Cascade Mts., 1882; W. N. Suksdorf, No. 883, 1886, No. 2208, Klickitat Co., 1893; Mrs. W. L. Steinweg, Cascade Mts., 1894; Kirk Whited, Weuatchee, 1896.

P. WOODHOUSEI (A. Gray) n. sp.

P. nana Torr. in Sitgreaves Rep. 115 (1853), not Nutt. *P. speciosa var. Woodhousei* A. Gray, Proc. Am. Acad. 8:256 (1870).

Low, 5-10 cm. high, stems few from a ligneous base, the short sterile ones very leafy, the flowering ones corymbosely branched above; glandular pubescent, usually glabrous below; leaves thick and rigid, those of the sterile shoots oblong-linear, abruptly acute, 3-4 cm. long, 3-5 mm. broad, those of the flowering stems shorter and often nearly oblong, not at all dilated at base; flowers few, on pedicels 5-20 mm. long; calyx about 7 mm. long; corolla pink (?), the tube usually twice the length of the calyx, the lobes cuneate-obcordate, usually deeply so, 6-8 mm. long; ovules solitary in each cell. Arizona. Type locality; "lat. 35°, long. 112° 20′."

A good species, having a distribution far removed from the species to which it has been allied. Its small size and oblong-linear leaves distinguish it. It is very leafy at base while the flowering stems are as a rule comparatively naked.

Specimens examined from Arizona: E. Coues and E. Palmer, Nos. 122, 210, 308 and 376, Fort Whipple, 1865; Anderson, Williams Mt., 1865; H. H. Rusby, Ash Fork, San Francisco Mts., 1883; M. E. Jones, San Francisco Mts., 1890.

††Ovules 2 to 3 in each cell; corolla lobes entire or nearly so.

P. TRIOVULATA Thurb. in Bot. Mex. Bound. 145 (1859).
P. nana var. glabella A. Gray, Proc. Am. Acad. 8:256 (1870).

Stems usually slender, simple or very little branched, 1-2 dm. high somewhat canescent-pubescent throughout or sometimes nearly glabrous; leaves nearly all opposite, linear, 3-4 cm. long, 1-2 mm. wide; flowers few and often solitary; calyx with sinuses very slightly replicate, each plica often produced into a tiny spur near the base of the calyx; corolla "white" or "purplish," the tube usually glabrous, somewhat exceeding the calyx, the lobes broadly obovate entire or erose-denticulate, about 12 mm. long; ovules 2 or 3 in each cell. New Mexico and Southeastern Arizona. Localities cited at place of original publication; "Ravines, Mule Spring," "Rio Mimbres" and "Escondido," New Mexico.

This is sufficiently dintinct from *P. nana* to be a species. Its slender habit and narrow leaves at once separate it from that. The corolla tube is also much more glabrous and the calyx sinuses are inclined to be a little replicate. It varies from somewhat canescent-pubescent to nearly glabrous. Originally it was described as "canescently pubescent," yet there are very few specimens to which that term can be applied. For that reason Dr. Gray placed *P. triovulata* as synonymn of *P. nana*, and named the slender glabrate form *P. nana var. glabella.* Such disposition is not satisfactory. for *P. triovulata* and *P. nana glabella* together constitute a distinct species, having the same slender stems and narrow leaves and differing only in the amount of pubescence. The two numbers,504 and 1654,which Dr.Gray cites as belonging to the smoothish variety, are also cited at the original place of publication of *P. triovulata*, and a specimen seen of the latter number is canescent-pubescent and has the tiny spurs mentioned in the description above.

Specimens examined: New Mexico; C. C. Wright, Nos. 504 (1849) and 1864 (1851-52); A. Wislizenus, 1846-1847; E. O. Wooton, Nos. 13 and 447, Organ Mountains, Dona Ana Co., No. 575, White Mountains, Lincoln Co., 1897: Arizona; J. G. Lemmon, No. 415, Rucher Valley, Chirricahua Mts., 1881.

P. NANA Nutt. Pl. Gamb. 153 (1848).

Herbaceous to the ground or somewhat ligneous at base, 1-2 dm. high, stems freely branched; roughish pubescent throughout and more or less glandular; leaves spreading, opposite below alternate above, lance-linear, on the main stems 20-35 mm. long, 3-4 mm. wide, on the lateral branches shorter and narrower; flowers scattered or somewhat corymbose, on pedicels 5-35 mm. long; calyx teeth slightly longer than the tube, green and apiculate; corolla "red" or "white," the tube pubescent, somewhat exceeding the calyx, the lobes broadly cuneate-obovate, entire or with wavy margins, often mucronate, about 15 mm. long; ovules 2 or 3 in each cell. Common in New Mexico, also in Arizona.

Specimens examined: New Mexico; A. Wislizenus, Las Vegas, 1846; A. Fendler, Santa Fe Creek Valley, 1847; T. S. Brandegee, Santa Fe Co., 1879; George Englemann, "Hills and mountain sides about Santa Fe and sandy soil along Santa Fe Creek," 1881; A. A. & E. Gertrude Heller, "Canon near Santa Fe," 1897: Arizona; J. W. Blankinship, Flagstaff, 1893.

****Annuals; calyx teeth spreading, linear or subulate-lanceolate.

setaceous-tipped, with age becoming recurved and split to the base or nearly so; corolla tube hairy near the base within; style not longer than the stigmas; ovules 1-5 in each cell. All Texan.

†Corolla tube pubescent, exceeding the calyx; ovules solitary in each cell.

P. ASPERA n. sp.

Annual (?) branched from the base, 12-17 cm. high, the stems simple and strict with opposite leaves up to the close cymose clusters of short-pedicelled flowers; pubescent throughout with short rigid hairs, the stems puberulent and with some longer spreading hairs, the pedicels and calyx glandular; leaves narrowly lanceolate to linear, 20-45 mm. long, 3-5 mm. wide, somewhat rigid and of firm texture; calyx teeth more or less purple, about twice the length of the tube, setaceous-tipped; corolla violet (?), the tube glandular-pubescent, nearly twice the length of the calyx, the lobes cunate-obovate, mucronate-acute, 12 mm. long; ovules solitary in each cell. Texas.

A well marked species, readily distinguished from *P. Drummondii* by its habit and entirely different character of pubescence. Type in Herb. Mo. Bot. Garden; collected by A. A. Heller at Kerrville, Kerr County, southern Texas, April 19-25, 1894.

P. DRUMMONDII Hook. Bot. Mag. t. 3441. Gray, Proc. Am. Acad. 8:257. Gray, Syn. Fl. 2:134.

Texas.

Specimens examined from Texas: Lindheimer; "Sandy tributary of Mill Creek," 1839; 1843; No. 275, 1844; Nos. 426 and 427, Victoria, 1845; 1847; No. 425, Victoria, 1848.

P. DRUMMONDII VILLOSISSIMA A. Gray, Proc. Am. Acad. 2:257 (1870). Gray, Syn. Fl. 2:134.

Type locality; "Texas, in the pebbly bed of the Nueces."

A. A. Heller's specimens from Neuces Bay, Neuces Co., March 12, 1894, is doubtfully referred here, notwitstanding its lack of viscosity and its smaller flowers.

P. TENUIS (A. Gray) n sp.

P. Drummondii var. tenuis A. Gray, Proc. Am. Acad. 8: 257 (1870). Gray, Syn. Fl. 2: 134.

Type locality; "Eastern Texas."

This should have specific rank. It is very distinct from *P. Drummondii* and no intermediate forms have been seen. It is a much smaller plant, entirely devoid of coarse villous hairs and only slightly pubescent or glabrate.

Specimens examined from Texas: F. Lindheimer, Victoria, 1845 (several specimens); E. Hall, Hempstead, Eastern Texas, 1872, No. 478; C. Wright, No. 11,964.

††Corolla tube glabrous, not exceeding the calyx; ovules 4-5 in each cell.

P. ROEMERIANA Scheele, Linnaea, 21: 752 (1848). *P. macrantha* Buckley, Proc. Acad. Phila. p. 5 (1862). Gray, Proc. Am. Acad. 8:257. Gray, Syn. Fl. 2: 134.

Texas.

Specimens examined: F. Lindheimer, No. 467, Camale Spring, 1845; No. 68, San Antonio, 1846; New Braunfels, 1848.

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UNIVERSITY OF WYOMING.

Agricultural College.

NINTH ANNUAL REPORT

. . . OF THE . . .

WYOMING EXPERIMENT STATION,

LARAMIE, WYOMING.

For the Fiscal Year 1898-99.

Wyoming Agricultural Experiment Station.

UNIVERSITY OF WYOMING.

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NINTH ANNUAL REPORT

. . . OF THE . . .

WYOMING AGRICULTURAL EXPERIMENT STATION.

I hereby submit the ninth annual report for the Wyoming Agricultural Experiment Station in compliance with congressional enactment. The report covers the work of the Station during the fiscal year ending June 30, 1899.

ORIGIN AND PURPOSE.

The Wyoming Agricultural Experiment Station is the department of research of the College of Agriculture of the University of Wyoming. Congress in 1887 appropriated $15,000 annually for this purpose, and on January 10, 1891, the Wyoming Legislature authorized the University of Wyoming to receive this appropriation. The work of the Station is to aid in the acquiring and diffusing among the people of the United States, and especially of Wyoming, useful and practical information on subjects connected with agriculture, to conduct scientific investigations and experiments on the physiology of plants and animals; to investigate animal and vegetable diseases and parasites; to chemically analyze soils and water and vegetable and animal products; to acclimate grains and grasses, fruits and vegetables, to our arid climate and high altitude; to ascertain the best methods of irrigation, and of retaining the moisture in the soil; to find the best breeds of stock, and the best varieties of field and garden crops for the various portions of Wyoming; and to carry on any other experiments which promise to benefit our agricultural and grazing interests.

The results of these experiments are published in the Station Bulletins, which are sent free upon request to residents of this State.

BULLETINS.

The bulletins published during the year 1898-99 have been four in number, the title and a brief summary of each being given below. These bulletins have been rather popular reports of the investigations by the station. Other more technical papers are published as a part of this report and are as follows: "Alkali Studies III," "Alkali Studies IV," "Meteorology for 1898." These are detailed reports of scientific investigations and observations.

The bulletins are:

NO. 38. CULTIVATED SHADE AND FOREST TREES.

This bulletin contains a report of all the experiments in growing shade and fruit tree which have been made by the Station. It shows what trees may be expected to succeed in different parts of the State and contains a brief account of some troublesome insect enemies of our trees.

NO. 39. ALKALI STUDIES II.

This is a somewhat popular report of the alkali investigations in the Departments of Chemistry and Agriculture. It gives a condensed account of some of the experiments which are reported in detail in the technical papers.

NO. 40. THE TREES OF WYOMING AND HOW TO KNOW THEM.

This report gives an account of all the trees found native in the State, with such simple descriptions and illustrations as will enable anyone, whether he be a botanical student or not, to recognize the different species. The Bulletin shows the value of our forests and the need of conserving them. It appeals to the people to make the home more attractive by planting trees, and is intended to awaken an interest in the subject among the teachers and schools of the State.

INDEX BULLETIN B.

This is a general index showing all Bulletins which have been issued up to the beginning of the present fiscal year and indexing Bulletins 27 to 37 inclusive.

PLANS OF STATION WORK FOR 1899-1900.

The following plans for the season of 1899-1900 have been well stated. It will be seen that most of them look to carrying out the new policy of the Station. They were recommended by the Station Council and approved by the Agricultural Committee of the Board of Trustees.

THE AGRICULTURIST AND HORTICULTURIST.

1. Irrigation investigation.
    - a. Co-operation with the Department in measurements of water on farms.
    - b. Measurements of water used on Experiment Farm.
    - c. Plat experiments, different amounts of water on the same crop.
    - d. Notes on sub-irrigation.
    - e. Evaporation.
2. Alkali investigations.
    - a. In the field—Effect of irrigation.
      Effect of green manures.
      Economic plants on alkali soil.
    - b. In the laboratory.
3. Soil work.
    - a. Permanent soil plat; same crop year after year.
    - b. Crops with and without cultivation.
    - c. Crops with and without rotation.
    - d. Alfalfa as a fertilizer.
4. Cereals.
    - a. Varieties of small grain.
    - b. Plat work including co-operation with the Department of Agriculture with Russian varieties.

5. Forage Crops—Cultivated and native, including co-operation with the Department of Agriculture.
6. Potatoes—With fertilizer—second season.
7. Horticulture.
    - a. Hardy fruits at Laramie and fruit notes at Lander and Sheridan.
    - b. Celery (varied treatment).
    - c. Garden—small amount of variety work.
    - d. Asparagus on alkali and good land.
    - e. Pedigreed potatoes.
    - f. Native trees and shrubs for decoration.
    - g. Floriculture for decoration.
8. Forestry—Co-operative with Division of Forestry.
9. Notes on injurious insects and collections.
10. Varieties of wheat at Laramie, Lander and Sheridan.

Approved by the Station Council April 6, 1899.

B. C. Buffum,
Agriculturist and Horticulturist.

THE BOTANIST.

1. The continuation of the field work and accumulation of data upon the subjects heretofore undertaken but as yet not completed. (As given for 1899.)
2. A co-operative study of alkali in its relation to plant life.
    - (1) The comparative structure of alkali resistant and non-resistant vegetation.
        - (a) External characteristics.
        - (b) Histology.
3. Experiments with promising forage plants.
    - (1) For normal soils.
    - (2) For alkali soils.

THE CHEMIST.

1. Effect of alkali on germination of seeds.
2. Analysis of soil and alkali.
3. Analysis of alkali-resisting plants.
4. Analysis of irrigation water.

THE GEOLOGIST.

1. Completion of the preliminary bulletin on the artesian basins of the State.
2. The origin of alkali.
    (1) The geological location of these salts and their relation to the various terranes.
    (2) The way alkali finds its way into the soils.
    (3) Preventing further accumulation if possible.
3. Wind erosion and its relation to soil formation in the arid districts.
4. To complete the preliminary work on the birds of Wyoming and arrange notes for publication.

THE PHYSICIST AND METEOROLOGIST.

1. Capillary movements of water in soils.
2. Evaporation from soils.
3. Continuation of the work of making observations and co-operating with the State and United States Weather Service.
4. Observations on the precipitation from as many places in the State as possible.
5. Observations upon the direction and force of the air currents at Laramie.
6. Study of terrestrial radiation and sunshine.

Report of the Station Council.

REPORT OF THE DIRECTOR.

The writer of this report, E. E. Smiley, succeeded F. P. Graves as President of the University of Wyoming and Director of the Agricultural Experiment Station, July 1st, 1898.

GOVERNMENT.

I deem it best to say somethings concerning the government of the Station, as this seems to have been nowhere explained in previous reports. The government of our Agricultural Experiment Station is vested in the Trustees of the University and the Agricultural Executive Committee of the Board, whose names appear on a preceding page. The officers of the Station are a director and a secretary, who, together with the heads of the different departments in botany, chemistry, geology, physics and meteorology, compose the Station Council; which body passes on all matters pertaining to Station work in the way of experimentation and research, and makes recommendations to the Agricultural Executive Committee. All plans of work by the heads of departments are first discussed and accepted, modified or rejected by the Station Council; this system insures the cooperation of the staff of Station workers and prevents scattered work and misapplied effort. Again, all bulletins published by the Station are first read before the Station Council and each member is free to criticise any questionable point of fact, extravagant statement or the general arrangement of the matter; and finally the bulletin may be either adopted and recommended to the Agricultural Executive Committee for publication, or it may be returned for revision, or be entirely rejected. Such has been the general policy governing the Station since its organization; and the fact that the workers have been a unit force, and so have made a combined atack on the important agricultural problems from all sides at the same time, has contributed largely to their success heretofore.

OBJECT.

The study and research of the Station are made as practical as possible, and have to do with the problems which in our opinion are of most importance to the farmers of the state. For example, the subject of irrigation and the alkali problem have been given much attention. At the present time, so far as we can we are co-operating with the Department of Agriculture at Washington in the new irrigation work being done under the direction of Mr. Elwood Mead, who has been for a number of years the efficient State Engineer of Wyoming, and is now connected with the office of Experiment Stations. The results of our work are being published from time to time. The carefully prepared bulletins, based as they are upon as thorough work as we can do, are offered to the people with the belief that they contain nothing but reliable information, upon which the greatest dependence may be placed.

The widely scattered population of the state has made it almost impossible for the Station to come into direct contact with our farmers. The farming communities are naturally located in the places most favorable to agriculture, and are sometimes separated from one another by mountain ranges and long distances; and with the funds at our command and the small number of our Station workers it has so far seemed impracticable to do any general farmers' institute work. However, when the time comes that it is possible for us to engage in this kind of work, we shall be glad to undertake it; because we believe it will prove most valuable in bringing the farmers and our Station into closer relation with each other. The Station workers would then become better acquainted with the farmers' needs, and the information offered by the Station could be better brought before the attention of the farmers.

FARM.

In July the Station was inspected by Dr. A. C. True, Director of Experiment Stations, who made some valuable suggestions in regard to the enlargement of our Experiment Farm at Laramie, in order that irrigation experiments might be more extensively carried on. Accordingly our original forty acres have been increased by a donation of an additional eighty acres of land, with water right for the same, from the Wyoming Central Land and Improvement Company. This land is presented to the Station to be held so long as it used for experimental purposes, and fills a long felt want in supplying land for irrigation on an adequate scale to furnish results of value to the arid west. This land has been fenced and forty acres plowed and put into crops this year.

The Station buildings are a small five-room cottage, a tool shed, and a shed used as a barn at the farm; and a barn and green-house on the University grounds. The farm is well equipped with implements and all needed machinery. The great need of the Station is a good-sized barn in which to store farm implements and grain, and to provide room for threshing and winnowing of seeds indoors. With only the amount which can be used each year for building purposes from the Hatch fund ($750) it is not possible to build more than in a very small way, and it would seem that the State will need to make some provision in the near future for more commodious buildings for the Station. In case work is ever begun in animal industry, it will be necessary to add to the buildings at considerable cost. When the vote of the last Legislature shall have been carried into effect and the present buildings in Laramie now occupied as a penitentiary shall have been abandoned for the new state building at Rawlins, will it not be practicing a wise economy for the next Legislature to turn over the old grounds and buildings here to the State Agricultural College of the University of Wyoming?

SUB-STATIONS.

The Saratoga and Wheatland farms have reverted to the original donors and the permanent improvements on these farms have been sold for what they would bring. The Sundance farm is still held by the University, but it has not seemed possible to rent the place and it is standing still without cultivation or the care it should have. This farm should be rented or disposed of as soon as possible; for it is not going to be creditable to the institution to have a farm in that or any other section of the state growing up to weeds and with the buildings and fences fast becoming dilapidated.

The Lander farm has been rented to Mrs. J. S. Meyer, who has paid a small cash rental in advance; and who agrees to seed down ten acres to alfalfa, and to care for the fruit, keeping notes on the same. It is with regret that we record the death of Mr. J. S. Meyer, who has been connected with the Station since its organization as Superintendent of the Lander farm.

The Sheridan farm has been rented again to Mr. George C. Shelter for a small cash rental with the understanding that he is to do certain co-operative experimental work, furnish reports of the fruits growing on the place, and keep the fences and buildings in repair.

It is hoped that at least the farms at Lander and Sheridan may in time receive sufficient support from the state to keep up valuable experimental work in those places. In a number of states, notably California, the state legislatures provide funds for the support of several outside Station farms; and it would seem that a small amount appropriated for this purpose would bring good returns to the people, and besides would show our good faith in receiving the generous donation from the federal government through the Hatch fund.

BULLETINS.

During the past year an important change has been made by the Station in the matter of its publications. It has been decided to make the bulletins that are published for distribution more popular in their nature, and such as will better meet the demands of our own farmers by giving them practical information. Already this change seems to have met with general approval. These more popular bulletins as they are published are not now sent to all the names on our mailing list throughout the United States, but they are widely distributed among the people of the state of Wyoming. It should be said, however, that the bulletins will finally reach every name on our official list; for the reason that they will be bound in with our annual report, which is usually sent the rounds. Consequently the purely technical papers will be published hereafter only as part of our annual report, and will not be for general distribution as in the past.

A description of our laboratories in the several departments of physics, chemistry, botany, horticulture and agriculture, has already been given in connection with our account of the Agricultural College on a preceding page.

Our library is fast growing. All bulletins sent us from other stations are saved, and as complete sets are obtained in sufficient number to make a volume they are bound in cloth.

REPORT OF AGRICULTURIST AND HORTICULTURIST.

The bulletins issued from this department during the year were No. 38, "Cultivated Shade and Forest Trees" and jointly with the department of chemistry bulletin No. 39, "Alkali Studies II." A bulletin has also been prepared for the station giving the results of a three year test in subsoiling but its publication has been deferred until September. The irrigation records and notes which have accumulated since 1892 have been collated; the amount of water used by the stations at Laramie and Wheatland and on the farm of J. W. Sigman near Laramie has been computed from the register sheets, and a bulletin on "Duty of Water" has been prepared for the U. S. Department of Agriculture.

The teaching in the agriculture college and university, and duties as Vice Director make it possible to devote only part of the time to research work. Heretofore it has been practically impossible to keep ahead of the mass of notes and recordswhich accumulate from year to year. The past year the position of students in the courses has been such that the teaching has not been as heavy, consisting, as it has, of two hours in the fall and winter terms and one hour in the spring term, so special attention was given to working up our records, and putting the notes in more permanent and available form. The crop record for 1898 is not completed but as a whole the notes have been more nearly brought up to date than for a number of years past. Mr. Fairfield devoted the larger part of his time during the winter months, to this work which consisted of sifting out and arranging the notes taken in day books, computing areas and yields, and assisting with the computations of flow of water, to determine the amount used on different crops.

The fact that the field of labor nominally covered by my department is too broad has long been recognized. The attainment of a man who claims to be a specialist in several branches, naturally falls under suspicion among scientists and to relieve the odium of such a position it would seem well to state briefly the conditions under which we labor, which enable me to look after several departments and do practically nothing in more than one or two lines of investigation. Agriculture in Wyoming is still very new compared with that of older states. The population is scattered and the range stock industries are still paramount to all others. There are comparatively few calls on the time of the station workers from other parts of the state and each head of a department may follow his investigations with comparatively little interference from extraneous sources. As yet the station workers have not been called upon to do any farmers institute work. During the history of the station but one paper has been prepared for a farmer's institute and the writer of the paper did not present it at the meeting. True there is considerable correspondence with farmers on the subjects of importance to them but up to the present time few inquiries have been received which called for extended investigation or experimentation before they could be answered.

As agriculturist and horticulturist I have charge of all the work which falls to those departments. A claim that I am a specialist in all the divisions of agriculture and horticulture would indicate a pitiable state of ignorance, to those who realize what such a statement would mean. However I am able to keep these departments alive by only giving attention to those things which promise to be of greatest immediate value to our farmers. But little horticulture exists in our state. There are probably not to exceed one hundred acres planted to fruit of all kinds and nothing is done of commercial importance in fruit growing. On account of the very newness of things there are no serious insect enemies, and as yet what insects of economic importance have appeared are well understood and easy to combat. On account of this same newness, and the natural fertility of arid lands the application of fertilizers has not required attention and even crop rotation is only beginning to receive attention. In agriculture we have given almost no attention to any phase of live stock or dairy work. The salts in the soil,. irrigation and cropping are the subjects which have received special attention and while the working force has been small we believe something is being accomplished of immediate value to our farmers. The teaching in the agricultural college and university requires considerable time and interferes with the original research work more than any other required duty.

The plans of work for last season as given in the eighth annual report were fully carried out, something being done on each line indicated. Last season was the third year of the sub-soil experiment, a report of which will be made in the next station bulletin. The permanent soil work, as established for several years, consists of two plats, one of which is planted to grain each year and the other planted in different crops, following a four years rotation. The grain plat is beginning to show the effects of planting to the same crop year after year. Either the land or the seed is running out and to determine which is the case a change of seed will be tried.

Our study of varieties of small grains has probably been carried out as far as will be profitable. As many varieties of wheat, oats and barley as could be obtained have been grown in small amounts for several years. The work has been expensive as each individual variety requires its own special care and complete record and all have to be rogued and selected to keep the seed pure. We believe we can select those varieties of greatest promise for this state and grow in larger fields for a few years to obtain sufficient amount of seed to give our farmers a start in them. The work promises to be of considerable value. Our high altitude and unusual conditions of soil and season make the variety to be grown, and its adaptability, of considerable importance. Earliness is a prime necessity in both oats and wheat and a shortening of the necessary season for grain to mature, of a week or ten days, insures plump, heavy grain instead of a frosted, shrunken, inferior product.

Perhaps the most important of all our work in cropping is that with forage plants. The amount of land which can be irrigated is small compared with the land which must always serve as pasturage in this state. Such conditions must ultimately fix a system of mixed farming in which stockraising will be the main object and the growing of hay and other stock food on the irrigated land undoubtedly will always be the principal part of our plant production. What then can the station do which will be of greater value to the state than to demonstrate how two blades of grass can be made to grow where only one grew before? So far as we have determined the forage which will resist drouth better than any other is the Sanfoin or Esparsette. The ones which resist alkali best are the White Sweet clover and English rape and the best all-round hay crop even at the altitude of the experiment station (7,200 feet) is alfalfa. Alfalfa produces from two to four times as much as any irrigated native grass. It solves the foxtail or any other weed problem and keeps up the land so large crops of grain or potatoes can be raised without other fertilizing. The new Turkestan alfalfa introduced by the United States Department of Agriculture seems to stand the winters and drouth better than the variety generally grown. During the past winter none of the Turkestan alfalfa died while all the other fields suffered more or less. At Laramie our average yield of alfalfa per acre, for three years past, has been over three and one-half tons and plats in which the stand has been best yield over four tons of cured hay. On account of the short season we can only cut alfalfa twice, and the second cutting is usually but a partial crop.

The flat pea (Lathyrus sylvestris) grows well and seems perfectly hardy, but there are two or three serious objections to it. First, it takes three or four years to get it to produce a heavy crop; second, the roots are so tough and deep seated that it is almost impossible to get it out of the land, and third, we have been unable to make stock eat the hay. This last objection to the flat pea is also the serious one with White Sweet clover, though it is claimed by people in Utah and in Mississippi that stock can be educated to eat Sweet clover hay. We have thought the hairy vetch a promising hay crop but nearly all of it was killed by the past severe winter.

The alkali and irrigation investigations have been spoken of elsewhere. Co-operative tests with sugar beets were discontinued this season as we believe the station has done all the work with sugar beets which circumstances warrant at present. Our experiments with fruits at Laramie prove that strawberries, currants and dewberries can be grown for home use. Other fruits have not succeeded. The fertilizer experiment carried out last season, using potash salts and barnyard manure for potatoes, did not give results which we believed were entirely trustworthy and the same plats were planted to potatoes again this season. It seems that the land is already so rich in sulphates and chlorides of sodium and magnesium that adding sulphate or chloride of potassium diminished instead of increased the crop. Even small applications of barnyard manure greatly increases the crop but sodium nitrate apparently does not produce a like effect. This indicates that the land needs humus rather than greater supply of nitrogen in any other form.

Last year we planted about three acres of land with small trees of Scotch, Austrian and Bull pines furnished by the Division of Forestry of the Department of Agriculture. A very small percent of the trees lived through the winter and the larger part of the land was put into other crops this year. It is unlikely that the growing of trees for any other purpose than shade and ornamentation will ever pay here, and we do not expect to carry out any further experiments with them unless it be in a very small way.

The equipment of the Station has been materially increased and improved during the year. The increase in the size of the experiment farm enables us to carry on some irrigation experiments on a practical scale. Eleven acres of the new land have been used for an investigation of the amount of water needed to produce a maximum crop. This investigation will probably be continued through a number of years. The old farm is all used for small plat work and alkali studies so it was impossible to branch out as we wished in the irrigation work. The new land, however, is ample for all our needs. We will not bring all of it under cultivation for some time. To the equipment have been added a Fairbanks and More gasoline engine of four-horse power, which is used for threshing and grinding grain, Farmer's No. 3 grain and bone mill, a Deering Ideal mowing machine, a new steel plow, and a twelve-foot windmill. A pumping packer was put into the well on the farm but as yet good water has not been obtained. Among the permanent improvements made may be mentioned finishing the upper floor in the cottage on the farm and adding a porch to the front. A small potting and store house was built at the east end of the greenhouse. A new germinating chamber was purchased for further study of the effect of alkali salts on seed germination. The greenhouse furnishes very good laboratory facilities for the department. Some new irrigation instruments have been purchased, including a current meter, two water registers, and a Brown hydrostatic level.

More room is needed on the farm in which to shelter implements. The only way the machinery can be put under cover now is to take it to pieces so it may be stored in a small space. This prevents keeping it under cover while in use now and even during the summer, without a great deal of extra time and trouble. An adequate building should be provided as soon as possible in which to store tools and grain and to furnish room for cleaning grain and seeds during the winter.

We have been fortunate in securing this year Mr. E. Sigman as farm foreman. It has been difficult to obtain good intelligent help for the farm labor, and Mr. Sigman has shown himself both capable and energetic. Mr. Fairfield has been efficient and faithful, taking a great interest in all the work. The success of the work depends in no small measure on such assistance. The man who is merely working for his daily wages is not apt to take that interest in his work which makes him efficient and indispensable to the employer who would have the best service. These men not only love the work but feel their responsibility and have reputations to make which mean success in life. Instead of working eight or ten hours a day their hours of labor are all the hours out of twenty-four that they are able to work. There is little danger of getting overpaid for such services, and it is hoped they may be kept in their present positions.

We have obtained much help during the year through student labor. A student has acted as stenographer and typewriter in the office, the insect collection has been overhauled and duplicates in recent collections brought together, and the larger part of the year the green house has been cared for by student help.

Last July I attended a conference of irrigation experts, in Denver, on invitation of the officials in the Department of Agriculture, to discuss the work in irrigation to be undertaken by the department. In September I attended the National Irrigation Congress in Cheyenne and in November I represented the experiment station at the meeting of the American Association of Agriculturual Colleges and Experiment Stations held in Washington.

REPORT OF THE BOTANIST.

Of the several lines of work projected for the year now closing only a few have received any considerable attention. There is so much to be done in each that only one or two can be successfully pursued at any one time. Data are being accumulated on various subjects but to bring them to a point warranting publication means much special attention.

One bulletin, "The Trees of Wyoming and How to Know Them," has been issued this year as No. 40 of this Station. It is a part of this report.

The botanical survey of the state is progressing as rapidly as other work will permit. During the summer of 1898 the botanist spent several weeks in study at the Missouri Botanical Garden, St. Louis, but during his absence field work was prosecuted by Mr. Elias Nelson. As a result of the efforts in this direction during the past few years the resources of the state are becoming fairly well known. Especial attention has been given to the indigenous forage plants and much information, which it is hoped may be of service, has been secured concerning the distribution and abundance of these.

Since the last report, the writer's investigation of the "Flora of the Red Desert and Its Forage Resources" has been published by the United States Department of Agriculture, being issued as Bulletin No. 13 from the Division of Agrostology.

The abundance, distribution and economic significance of the fungi affecting native and crop plants is still a subject of inquiry. While not of so much significance here as in some other states yet it is of interest now and will become more so as agricultural interests are developed.

Besides the plants of direct economic significance the survey of the state is bringing to light many of much general interest, among them many new species. As rapidly as possible these are being described and published, there having been issued since July 1, 1898, the following papers: III, IV, V, VI and VII in the series "New Plants from Wyoming." This series is appearing in the Bulletin of the Torrey Botanical Club, the foregoing papers having been issued in the July and October numbers of 1898 and the January, March and May numbers of 1899 respectively. Other papers have been prepared and are in the way of publication but may not find space for some months to come.

Certain genera are so abundantly represented in this range as to make them to a degree the characteristic plants of our flora. Some of these have received much study and, on account of the new species each includes, have proven of so much interest as to warrant the preparation of special papers upon each. Just issued in the June number of Erythea is "The Western Species of Aragallus." The following are in course of publication: "Some Rocky Mountain Chrysothamni;" "New Species in Oreocarya and Its Allies;" "Some Species of Tetraneuris and Its Allies."

Reference may here also be made, as bearing upon the botanical survey work, to the "Revision of the Western North American Phloxes," by Mr. Elians Nelson. It is published as a part of the Ninth Annual Report of the Agricultural College, which is bound herewith and to which attention is called.

Among the subjects of investigation the present season are the forage plants of northwestern Wyoming, including Yellowstone Park and the adjacent Forest Reserves.

REPORT OF THE CHEMIST.

The work of the chemist during the year has been principally confined to the study of the effect of alkali on the imbibition of water by seeds and their germination, the results of which are published in Studies III and IV in this report. In addition to this a number of soil samples taken from different depths of the Laramie Farm have been analyzed to get a better idea of the movements of the alkali under irrigation.

REPORT OF THE GEOLOGIST.

During the year there were collected considerable data pertaining to the various lines of investigation. The following work is under way:

The Artesian Basins in Wyoming.

Wind Erosion and its Relation to Soil Making in the Arid Region.

The Origin of Alkali.

The Birds of Wyoming.

The bulletin on the Artesian Basin in Wyoming is still in course of preparation. It has been utterly impossible, owing to the rush of work, to make the geological maps and section and to work up my notes for the bulletin. It will be, when printed, quite an extensive discussion of the subject. I have also taken valuable notes in wind erosion at all points visited in the state.

Since the state has concluded to take up the subject of alkali and to work out all the problems in connection with it in Wyoming, I have been assigned the subject of the Origin of Alkali. I realize that it is a great problem to undertake to solve, but there is not a better field to work in than Wyoming to accomplish this end. During the coming season I expect to add some valuable data pertaining to this subject.

REPORT OF THE METEOROLOGIST AND PHYSICIST.

Observations in the Meteorological Department have been taken of the relative humidity, maximum and minimum temperatures, pressure of the air, rainfall, snowfall, velocity and direction of the wind, evaporation, percentage of sunshine, and temperature of the soil at various depths.

On account of the interference of the University building with the air current, especially when the wind was blowing from the west, the steel tower on which are the anemometer and wind vane was moved to a distance of 800 feet away from the buildings.

All observations, except amount of rainfall and snowfall, are taken each day at 7 a. m. and 7 p. m.

In the physical department the following are some of the problems which are being investigated as rapidly as circumstances will permit:

Capillary movements of water in soils.

Evaporation of moisture from the surface of soils.

Puddling of soils.

TREASURER'S REPORT.

UNIVERSITY OF WYOMING.
AGRICULTURAL EXPERIMENT STATION,
LARAMIE, WYOMING,
. . . In Account With . . .
THE UNITED STATES APPROPRIATION, 1898-99.

DR.

To receipts from the Treasurer of the United States as per appropriation for fiscal year ending June 30, 1899, as per Act of Congress approved March 2, 1887....................$15,000.00

CR.

By	Salaries	$ 5,090.00
	Labor	2,735.99
	Publications	1,170.02
	Postage and stationery	472.96
	Freight and express	234.71
	Heat, light and water	887.61
	Chemical supplies	515.87
	Seeds, plants and sundry supplies	260.38
	Fertilizers	8.35
	Feeding stuffs	34.92
	Library	79.90
	Tools, machinery and implements	705.23

Furniture and fixtures		349.52
Scientific apparatus		795.00
Traveling expenses		842.95
Contingent expenses		66.59
Building and repairs		750.00
Total	$15,000.00	$15,000.00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the University of Wyoming Agricultural Experiment Station for the fiscal year ending June 30, 1899; that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $15,000 and the corresponding disbursements $15,000; for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving no balance on hand.

And we further certify that the expenditures have been solely for the purposes set forth in the Act of Congress approved March 2, 1887.

Signed: Melvile C. Brown,
Henry L. Stevens,
Auditors.

Attest:
Grace Raymond Hebard,
Secretary.

SUPPLEMENTARY STATEMENT.

	Fees	Farm Products	Miscel-laneous.	Total
DR.				
To receipts from other sources than the United States for the year ending June 30, 1899	$70.90	$100.00	$300.00	$470.90
CR.				
Scientific apparatus			123.00	
Buildings and repairs	70.90	100.00	177.00	
Total				$470.90

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Meteorological Report for 1898, by C. B. Ridgaway.

Bulletin No. 38. Cultivated Shade and Forest Trees, by B. C. Buffum.

Bulletin No. 39. Alkali Studies, II, by E. E. Slosson and B. C. Buffum.

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ALKALI STUDIES, III.

BY B. C. BUFFUM.

PUBLISHED AS PART OF THE NINTH ANNUAL REPORT OF THE
WYOMING AGRICULTURAL EXPERIMENT
STATION.

JULY, 1899.

LARAMIE, WYOMING.

ALKALI STUDIES, III.

Germinating Experiments With Alkali Salts.

BY B. C. BUFFUM.

That concentrated solutions of the salts commonly found in soils do retard germination was demonstrated and published in Bulletin No. 29 of this station. Since that time the subject has been given considerable attention in our station and by others engaged in scientific research. The experiments here reported were carried out by Mr. W. H. Fairfield, assistant in this department. A resume of a part of the work was given in Bulletin No. 39, which is bound with this report. The importance of the subject and the certainty that future references will be made to this work, will make valuable a detailed account of the experiment and the results obtained.

Alkali, as commonly known, consists of the several soluble salts of the soil, which accumulate in sufficient amount to become noticeable in white incrustations on the surface, or in their effect on water, soil, and vegetation. Our first germinating tests were made with the associated salts as they occurred in the soil of the experiment farm. The amount of any one of the salts making up this compound varies widely in different places and undoubtedly at different times in the same place. Generally the salt making up the larger portion of the alkali is sodium sulphate or magnesium sulphate, but in places it is sodium chloride or as sometimes occurs in this state, it may be sodium carbonate. In order then to arrive at definite conclusions in regard to the effect of alkali it seems important to study the relative effect of each salt. This experiment shows that each salt differs widely from the others in its effect on seed germination and plant growth, and has led to further study of the reason for such effects. The study was continued by Professor Slosson, who made a preliminary report in Bulletin No. 39, and reference is here made to his paper, "Alkali Studies IV," also published as part of the Ninth Annual Report. The following experiments are reported as they were written out by Mr. Fairfield, with slight modifications and changes in arrangement:

EFFECT OF DIFFERENT SALTS ON THE GERMINATION OF SEEDS.

To determine the effect of each salt which makes up the alkali of the arid region, seeds were germinated in solutions of varying strengths of sodium chloride, sodium sulphate, sodium carbonate and magnesium sulphate. The two chief points that the test was intended to determine,stated briefly, are: First, the relative effects of different percents of the same salt on the germination of wheat, rye, and White Sweet clover (*Melilotus alba*); second, the relative effect of the same percent of the different salts on the germination of these seeds. It was thought that the osmotic pressure of the salt solution might influence the imbibition of water and account for the retardation of germination. We had previously found that concentrated salt solutions prevented the rapid imbibition of water.* An article in the Botanical Gazette for December, 1897, on "The Relation of Nutrient Salts to Turgor," by Copeland, suggested to the chemist that osmotic pressure might account for such effect rather than any physiological action of salts on the plant tissues. To throw light on this point a series of sugar solutions were also used, as the osmotic pressure of sugar is comparatively low.

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*See Bulletin No. 29, P. 235.

Solutions containing 0.1, 0.4, 0.7, 1.0, 2.0, 3.0, 4.0, 5.0, 7.0 and 9.0 percents of each of the salts named and also of sugar were used to germinate the seeds. Fifty seeds of Chili wheat, Spring rye, and White Sweet clover, which had been carefully hand-picked and counted, were tested in each of the solutions containing the above percents of the salts and sugar, and a check was carried out in pure water.

OUTLINE OF EXPERIMENT.

Stock solutions of the salts to be used as well as of sugar were made so that, when everything was ready, as little time as possible might be used in converting the solutions into the various strengths desired. Certain quantities of the salts of sodium sulphate, sodium carbonate, and magnesium sulphate were dried by heating to a red heat and holding them at this temperature for a short time. The sodium chloride was dried at a little lower temperature. The stock solutions were made up as soon after the salts were dried as possible. Granulated sugar was used for the sugar solutions.

Some little time was spent in determining the best germinating device. The great difficulty to be overcome in carrying out the test was the question of evaporation. This would not only change, quite rapidly, the strength of the solutions, but as the seeds must of necessity be at or near the surface, they would be surrounded continually with stronger solutions. The first method adopted was to lay the seeds between two pieces of rather fine cheese-cloth and float them on cork in plates so that the upper surface of the cork carrying the cloth would be about even with the surface of the water. It might be well to state here that this first entire germination test, carried on in the greenhouse, was continued for fourteen days, careful observations being taken each day on the number of seeds germinated, and every precaution taken to keep the conditions uniform. After carrying the experiment this far it was evident from the small number that had germinated that the seeds were in unfavorable conditions. After the first few days of the experiment the corks became saturated, lost buoyancy and sank lower, causing the seeds to be surrounded with the solution. The fact that the seeds were under such unfavorable conditions for germination made the results obtained, though comparable to a certain extent, rather unreliable. The test was therefore abandoned and was not begun again until some check tests were made to determine a method of procedure which would furnish conditions least adverse to the ready germination of the seeds, but which would still reduce the effect of evaporation to the least practical point. The following table gives the results obtained from a germination test in water under the different conditions named:

Wheat.				*Rye.*			
Number of days from beginning of test.	Fifty seeds between cloths floated on cork.	Fifty seeds between cloths on inverted saucers in the light.	Fifty seeds between cloths on inverted saucers in the dark.	Number of days from beginning of test.	Fifty seeds between cloths floated on cork.	Fifty seeds between cloths on inverted saucers in the light.	Fifty seeds between cloths on inverted saucers in the dark.
	Number germinated.	*Number germinated.*	*Number Germinated.*		*Number germinated.*	*Number germinated.*	*Number germinated.*
1				1		1	17
2	5	2	12	2	15	27	45
3	8	5	20	3	22	39	46
4	10	7	27	4	27	44	
5	No more germinated.	19	34	5	28	45	
6		24	36	6		48	
7		26	40	7			

In the table it will be noted that, with one exception, the seeds between cloths placed on the inverted flower-pot saucers germinated much more rapidly and completely than those placed between cloths floated on cork. The marked difference in the number germinated in the dark and in the light in the case of both kinds of seed is of interest.

So in beginning the experiment again two large boxes were arranged with shelves to hold the plates. All cracks in the boxes were stopped up to shut out the light as much as possible. These boxes were placed on the center bench of a double-span greenhouse, on sand which was kept somewhat moist throughout the experiment. Granite iron and tin pieplates were used to hold the solutions, the tin plates having previously received two coats of asphalt varnish on the inside to prevent rusting. The cloths which had been used in the previous tests were thoroughly washed in hot water, rinsed, and then boiled for ten minutes. The plates were also thoroughly washed. Saucers for five-inch flower-pots were washed, turned upside down, and the cloth placed on them. Solutions of the required strengths were made up from the stock solutions on hand with the exception of sugar, which was made fresh, the stock solution having collected some impurities. The weight of each, together with the inverted saucer, etc., was taken as the solutions were added and marked permanently on the outside of the plates. The plates could be readily weighed at any time desired and enough water added to bring back to the initial weight, thus compensating for any loss by evaporation and also keeping the solution at practically the same strength. Seeds of Chili wheat and Spring rye had been carefully hand-selected, only perfect, plump, and as nearly uniform kernels as possible being taken. These had also been counted and fifty seeds of each been placed in separate bottles so that all the seeds were placed between cloths at about the same time. Fifty seeds were used in each test. In the first experiment seeds of White Sweet clover were tested on account of the apparent ability of this plant to flourish in alkali soils. But though great pains were taken to get mature seed of last season's growth, not more than two or three percent germinated under the most favorable circumstances, so in the second experiment these seeds were left out and only wheat and rye were used. On February

26, between 1:30 and 4:30 p. m., the seeds were placed on the cloths which were laid over the inverted saucers. One end of the cloth was allowed to project farther than the other and this was now folded back over the seeds. This, therefore, left the seeds with one thickness of cheese-cloth between them and the saucer and one thickness over them. The edges of the cloth dipped into the solutions. The tops of the saucers were about a quarter of an inch above the surface of the solutions. The plates were weighed occasionally during the test and enough water was added at these times to bring them back to their original weight, but the evaporation was not great. Once or twice a day the cloths which contained seeds were dipped into the solutions. On March 16 the experiment was stopped and the final observations were taken. This carried the experiment through eighteen days.

The number germinated was carefully observed. The seeds were removed as fast as they germinated. Complete notes were kept on everything which might influence the results in any way, such as the time of the day each plate was examined, and variation in the condition or appearance of the seeds on any particular plate, etc. In the following tables, the number germinated each day, beginning the first day after the seeds were planted, is given. The results have been tabulated in this way so that they may be more easily compared. Whenever blank spaces occur in the tables they indicate that no seeds were germinated that day. To determine the variation in the germination of different sets of fifty seeds, due to their vitality, etc., two plates were used with simply water. An average of the results also gives a more reliable check for comparison. The results of the two tests run in water as well as the arbitrary average taken are given in the first two tables. The reason for taking an arbitrary average rather than an absolute one, is that it may be expressed in whole numbers.

Table giving the results from two tests in water, showing the unavoidable variations in the number germinated due to the difference in the vitality of the seeds, etc., and giving the arbitrary average used in the following tables:

Wheat.				*Rye.*			
Number of days from beginning of test.	Plate No. 1.	Plate No. 52.	Arbitrary average.	Number of days from beginning of test.	Plate No. 1.	Plate No. 52.	Arbitrary average.
1		2*	1	1	16	31	24
2	12	18	15	2	46	47	46
3	23	26	24	3	47	48	47
4	27	31	29	4			
5	32	32	32	5			
6	34	35	34	6			
7	36	37	37	7			
8				8			
9	40		39	9			
10	41		40	10			
11	42	39		11			
12	44		41	12			
13		40	42	13			
14			43	14			
15	45	41	44	15			
16				16			
17				17			
18		43		18			

*These two seeds were barely germinated when the observations were taken for the first day.

The following charts and tables give the relative effects of the same percents of the different salts used in the germination of wheat and rye. Charts of the rye have not been made because the seed germinated so rapidly. In the water all the seeds that had sufficient vitality to germinate at all began growing in three days. The fact that wheat germinated so much more slowly in all the solutions gives an opportunity for the study of the relative effects of the different solutions in graphic form in the charts. The variations are somewhat irregular, but this may be due to different causes, the principal one probably being the difference in the vitality of the fifty seeds in each test. In the charts the abscissas represent the number of days from the beginning of the test and the ordinates the number of seeds germinated. The line representing water is the same through all the charts, being the check.

In the chart represting the 0.1 percent solutions the sodium carbonate curve makes a marked variation from the water curve, there being twenty-four seeds germinated the second day, against sixteen in water, and on the following days the difference in the number germinated remains as marked.

In the 0.4 percent chart it will be noted that, from the fourth day on, all the salt curves precede the water curves. The fact that the seeds in all salt solutions at this percent germinated quicker than in water, regardless of the daily variations, shows a stimulating effect which is of interest.

That a small amount of alkali does aid in the germination of seeds is substantiated by some of the results given in the report of the germination experiment in Bulletin No. 29 of this Station. Referring to that report it will be seen that seeds germinated more readily in soil containing a small amount of salts than in leached soil. It is very interesting that a small amount of salt should facilitate the process of germination. Is the salt a factor in the process of converting the plant food stored up in the seed into an available form for the use of the growing embryo? Does the presence of the *very* small amount of the salts influence the turgor in the cells of the germinating seed and thus cause this beneficial result? Copeland, in his article, "The Relation of Nutrient Salts to Turgor," in the December number of the Botanical Gazette for 1897, states that potassium increases the turgor in the cells of the plant. He does not believe that sodium has an equal effect, but it has occurred to me that the very small amounts of the salts used in this experiment might so influence the turgor in the seed as to produce the marked effect on germination. No marked stimulating effect was produced by sodium chloride.

In the 0.7 percent solution chart the curves remain somewhat close to the water curves, though the sodium carbonate drops down a little. This indicates that, with the exception of the latter, solutions of the salts at this percent have no marked effect on the germination.

The 1 percent solution chart indicates that sodium carbonate at this strength retards germination decidedly.

In the 2 percent, 3 percent, 4 percent and on up to the 9 percent solution charts, the retarding effects are shown to increase very rapidly.

It is apparent from the experiment that the retarding effects of the different solutions are in proportion to their osmotic pressures. Professor Slosson has worked out the osmotic pressures of 1 percent solutions of the salts and also of the sugar and has kindly furnished them. They are as follows:

"1 percent sodium chloride equals 7.4 atmospheres.
1 percent sodiuum carbonate equals 4.3 atmospheres.
1 percent sodium sulphate equals 3.9 atmospheres.
1 percent magnesium sulphate equals 2.8 atmospheres.
1 percent sugar equals 0.7 atmospheres."

If the osmotic pressure of the different salts is the cause, or one of the principal causes, of the retarding effect they exert, the curves showing the respective effects of the different salts should arrange themselves in the order of their osmotic pressure. It will be seen at a glance that sodium carbonate, from the 1 percent solutions up, has a greater retarding effect than any of the others, which would not be the case if caused only by the difference in osmotic pressure. This is without doubt due to its caustic effect on the seed, which would be considerable in the solutions containing the higher percents of the salts. This fact, that sodium carbonate is alkaline and that the other salts used are neutral, puts it at once in a different category. Then if we confine ourselves to the other salts we find that from 3 percent up they arrange themselves in the order of their osmotic pressure. Below 3 percent the relative retarding effect of the salts seems to be quite irregular, probably because the osmotic pressures are not great enough to make a marked difference. The 5 percent solution chart shows variation in this order, the sodium sulphate and magnesium sulphate curves cross, but owing to the fact that the order is maintained in the higher precents this variation probably is not important. Solutions of sugar are used in the experiment in order that we might be able to compare the effect of this substance on the germination of seeds with the effects produced by the salts used. It is probable that any retarding effect sugar might be found to have, would be due to osmotic pressure alone. Sugar has a low osmotic pressure compared with the salts used but when the solution is sufficiently concentrated, (from 5 percent up) its curve drops below that of water. It is of interest to compare the 9 percent sugar curve with the 1 percent sodium chloride and the 2 percent sodium sulphate curves, as the osmotic pressure of each of the solutions is nearly the same. There is a marked difference in the osmotic pressure of sodium chloride and sodium sulphate, that of the former being nearly twice that of the latter. In the charts there is an analagous difference in their respective curves in the higher percents. Between sodium sulphate and magnesium sulphate there is not so much difference in the osmotic pressure, and in the charts there is not the difference in their curves. These results indicate conclusively that the retarding effect of a salt solution on the germination of seeds is in direct proportion to its osmotic pressure when the solutions are strong.

TABLE I.—*Rye in Sugar.*

Table showing number of seeds germinated each day in the different percents.

Number of days from beginning of test.	Water.	0.1 percent.	0.4 percent.	0.7 percent.	1 percent.	2 percent.	3 percent.	4 percent.	5 percent.	7 percent.	9 percent.
1	24	28	18	28	21	16	28	7	16	4	15
2	46	46	45	50	47	40	47	42	46	43	45
3	47	48	47		48	43		44	48	47	48
4			48			44				48	
5									49		
6											
7											
8										49	
9											
10											
11							48.				
12											
13											
14											
15											
16											
17											
18											

TABLE II.—*Rye in Magnesium Sulphate.*

Table showing number of seeds germinated each day in the different percents.

Number of days from beginning of test.	Water.	0.1 percent.	0.4 percent.	0.7 percent.	1 percent.	2 percent.	3 percent.	4 percent.	5 percent.	7 percent.	9 percent.
1	24	19	29	27	19						
2	46	40	45	47	45	34	42	19	15	8	
3	47	46	48	50	47	40	46	27	26	17	
4						41		30	32	24	21
5						42		33	33	25	24
6											26
7					48						
8								34		26	
9											
10											
11											27
12											
13											
14											28
15											
16										27	
17											
18											

TABLE III.—*Rye in Sodium Sulphate.*

Table showing number of seeds germinated each day in the different percents.

Number of days from beginning of test.	Water.	0.1 percent.	0.4 percent.	0.7 percent.	1 percent.	2 percent.	3 percent.	4 percent.	5 percent.	7 percent.	9 percent.
1	24	30	17	27	13	4					
2	46	47	47	46	40	32	14	3			
3	47	49	48	48	43	35	22	15	8		
4					45	38	24	25	21	11	
5							27	27	22	13	6
6						39		29			7
7								30	23		
8											
9								32			
10											
11											
12							28				
13											
14											
15											
16											
17											
18											

TABLE IV.—*Rye in Sodium Carbonate.*

Table showing number of seeds germinated each day in the different percents.

Number of days from beginning of test.	Water.	0.1 percent.	0.4 percent.	0.7 percent.	1 percent.	2 percent.	3 percent.	4 percent.	5 percent.	7 percent.	9 percent.
1	24	28	13	21	21						
2	46	46	38	38	26	6	2	1			
3	47		41	40		7	7	2			
4			42			9	9				
5			43	41							
6							11				
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											

TABLE V.—*Rye in Sodium Chloride.*

Table showing number of seeds germinated each day in the different percents.

Number of days from beginning of test.	Water.	0.1 percent.	0.4 percent.	0.7 percent.	1 percent.	2 percent.	3 percent.	4 percent.	5 percent.	7 percent.	9 percent.
1	24	23	14	8	3	1					
2	46	46	41	40	32	17	1				
3	47	48	48	42	43	27	6				
4				44		30	14	4			
5				46		31	16	7	4		
6						33	18		5		
7								8	6		
8											
9								9			
10											
11							19				
12											
13											
14											
15											1
16											
17											
18											

TABLE VI.—*Wheat in Sugar.*

Table showing number of seeds germinated each day in the different percents.

Number of days from beginning of test.	Water.	0.1 percent.	0.4 percent.	0.7 percent.	1 percent.	2 percent.	3 percent.	4 percent.	5 percent.	7 percent.	9 percent.
1	1	1								1	1
2	15	19	17	15	12	15	16	16	14	7	6
3	24	28	29	30	31	20	25	30	24	22	14
4	20	32	30	32	35	24	30	36	31	29	21
5	32	34	33	34	37	29	41	40	32	32	25
6	34	38	36	30		34	44		33	34	26
7	37	39	37	44				41	35	36	27
8		41								37	
9	39	42		45			45	42	36		32
10	40		38		38					38	
11		43	39		39	35			37	39	
12	41										
13	42		40					43			
14	43					36	47			40	34
15	44			47	40	37					
16						38			38		35
17		44									
18									39		

TABLE VII.—*Wheat in Magnesium Sulphate.*

Table showing number of seeds germinated each day in the different percents.

Number of days from beginning of test.	Water.	0.1 percent.	0.4 percent.	0.7 percent.	1 percent.	2 percent.	3 percent.	4 percent.	5 percent.	7 percent.	9 percent.
1	1										
2	15	12	11	15	11	7	4				
3	24	25	30	31	29	17	20	11	3	1	
4	29	29	35	34	31	32	30	25	16	9	
5	32	31	42	35	34	36	39	30	20	24	16
6	34	35	45	36		38	41	31	21	25	20
7	37	36		39	37	39					21
8				40						26	
9	39			42				33			22
10	40	40		43	39						
11		41		44	41					27	
12	41	42	46							28	
13	42							36			
14	43	43	47				42				24
15	44			45	43			38			27
16			48	46	44		43		22	29	
17				47							
18		44	50								28

TABLE VIII.—*Wheat in Sodium Sulphate.*

Table showing number of seeds germinated each day in the different percents.

Number of days from beginning of test.	Water.	0.1 percent.	0.4 percent.	0.7 percent.	1 percent.	2 percent.	3 percent.	4 percent.	5 percent.	7 percent.	9 percent.
1	1	2									
2	15	12	13	6	3	2					
3	24	19	33	23	23	12	9	7			
4	29	24	35	30	32	20	19	14	4		
5	32	30	36	33	36	23	28	18	16	6	
6	34	32	39	34	37	24	30	22	21		1
7	37	33		36		25		23	23		
8				38							
9	39	35		39	38	27	32	25			
10	40	36	40			28		26			
11		40	42	40							
12	41								24		
13	42		44	42				28	28		
14	43			45		32	33				
15	44						34	31	29		
16		42				33	35		31		2
17								32			
18		43						33			

TABLE IX.—*Wheat in Sodium Carbonate.*

Table showing number of seeds germinated each day in the different percents.

Number of days from beginning of test.	Water.	0.1 percent.	0.4 percent.	0.7 percent.	1 percent.	2 percent.	3 percent.	4 percent.	5 percent.	7 percent.	9 percent.
1	1										
2	15	24	3	3							
3	24	37	21	21	6	1					
4	29	41	30	28	8	7	5				
5	32	42	37	31	18	12	6				
6	34	43	38	32	21		7	2			
7	37			35	22	14					
8			40								
9	39										
10	40	45									
11		46	43			15					
12	41										
13	42		44	37							
14	43										
15	44	47	45	38							
16		49		39							
17											
18		50									

TABLE X.—*Wheat in Sodium Chloride.*

Table showing number of seeds germinated each day in the different percents.

Number of days from beginning of test.	Water.	0.1 percent.	0.4 percent.	0.7 percent.	1 percent.	2 percent.	3 percent.	4 percent.	5 percent.	7 percent.	9 percent.
1	1										
2	15	12	7	5							
3	24	19	25	20	9	5					
4	29	28	31	32	22	19	2				
5	32	33	35	33	30	29	4	1			
6	34	34	37	34	34	33	6	5			
7	37	38			35						
8			38	35							
9	39		39	37			10				
10	40		40	38	36		11				
11		39				34	12				
12	41					35					
13	42										
14	43	41			37						
15	44	42									
16							14				
17								7			
18						39	16				

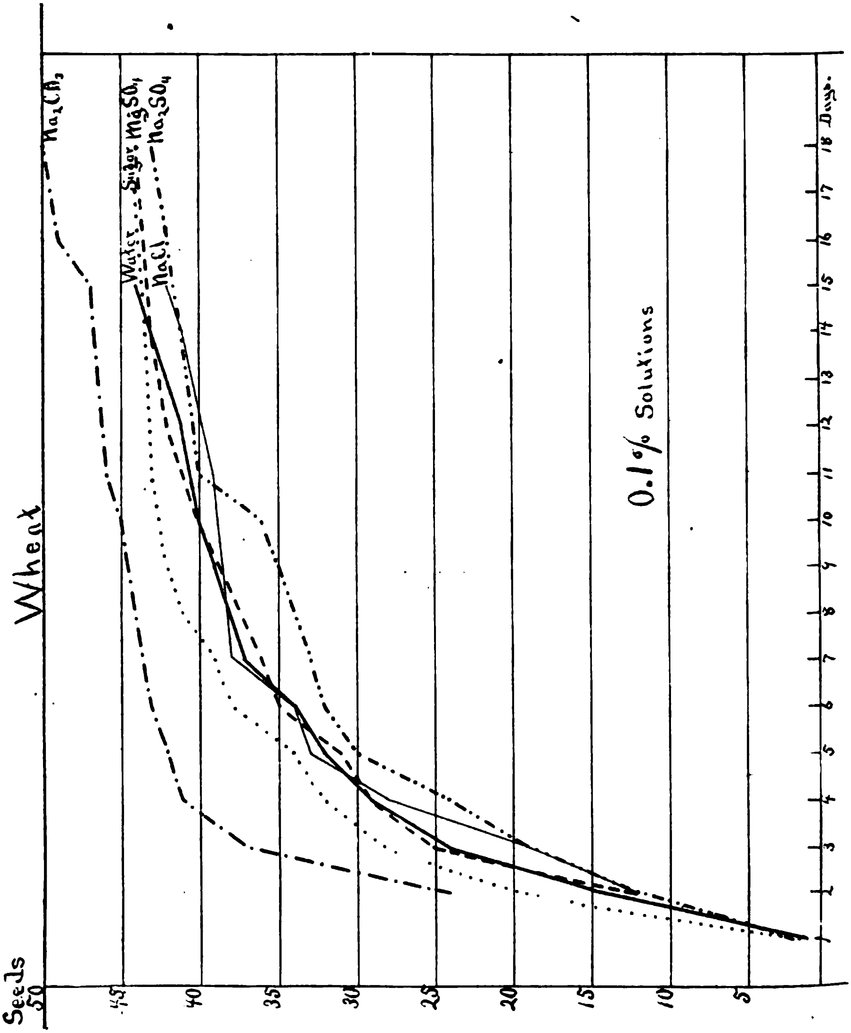

Wheat
0.1% Solutions
Seeds
50
45
40
35
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18 Days.
Na₂CO₃
Water
Sugar
MgSO₄
Na₂SO₄
NaCl

CHART I.

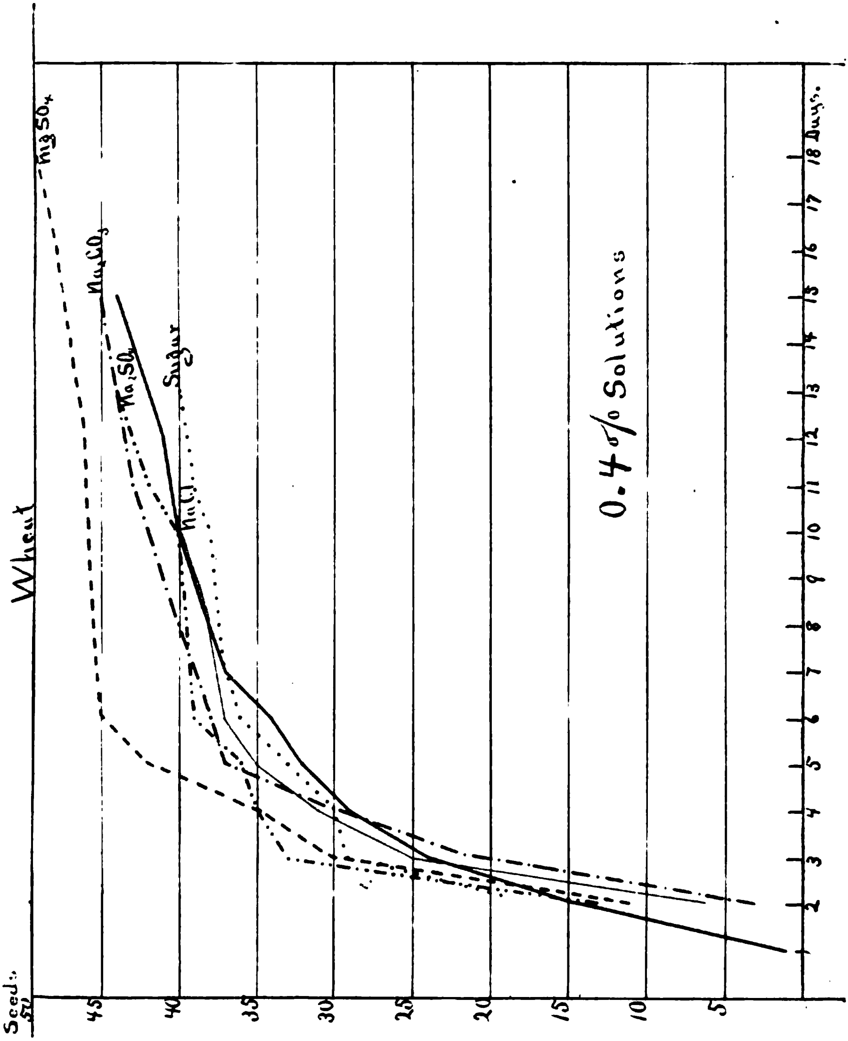

Wheat
0.4% Solutions
MgSO4
Na2CO3
Na2SO4
Sugar
NaCl
Seeds 50
45
40
35
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18 Days.

CHART II.

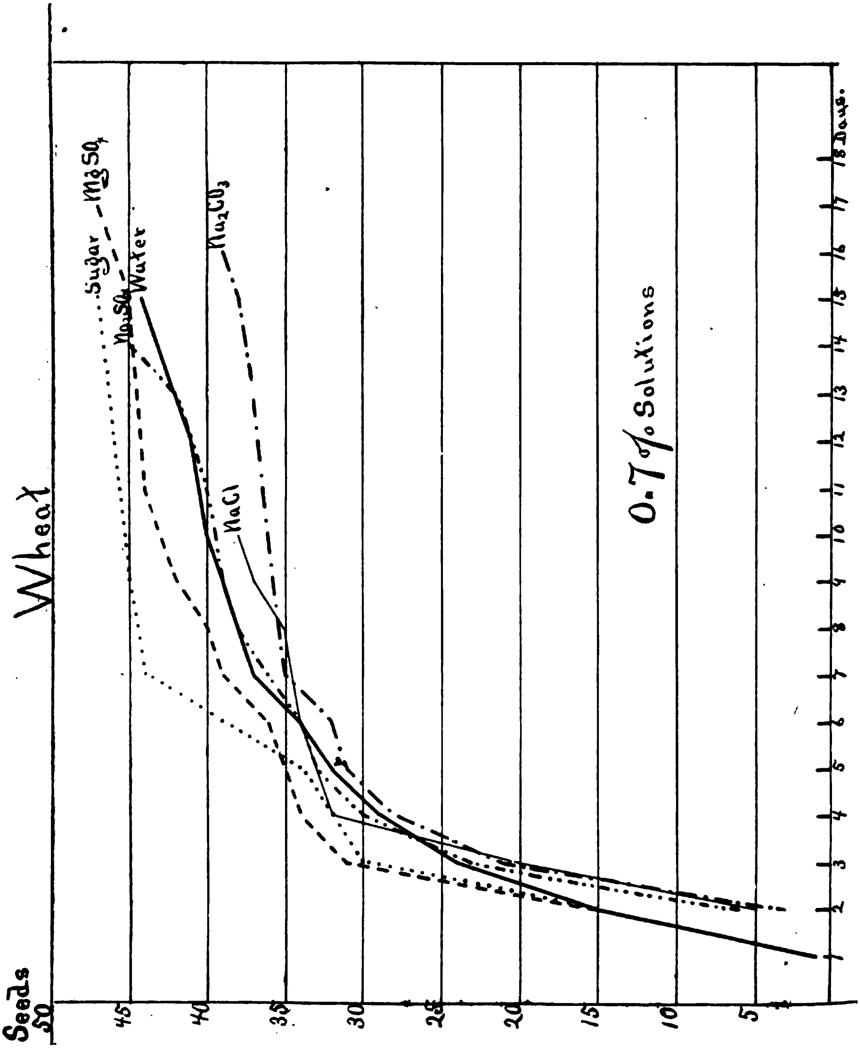

Wheat
0.7% Solutions
Seeds
50
45
40
35
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18 Days.
Sugar
$MgSO_4$
Na_2SO_4
Water
Na_2CO_3
NaCl

CHART III.

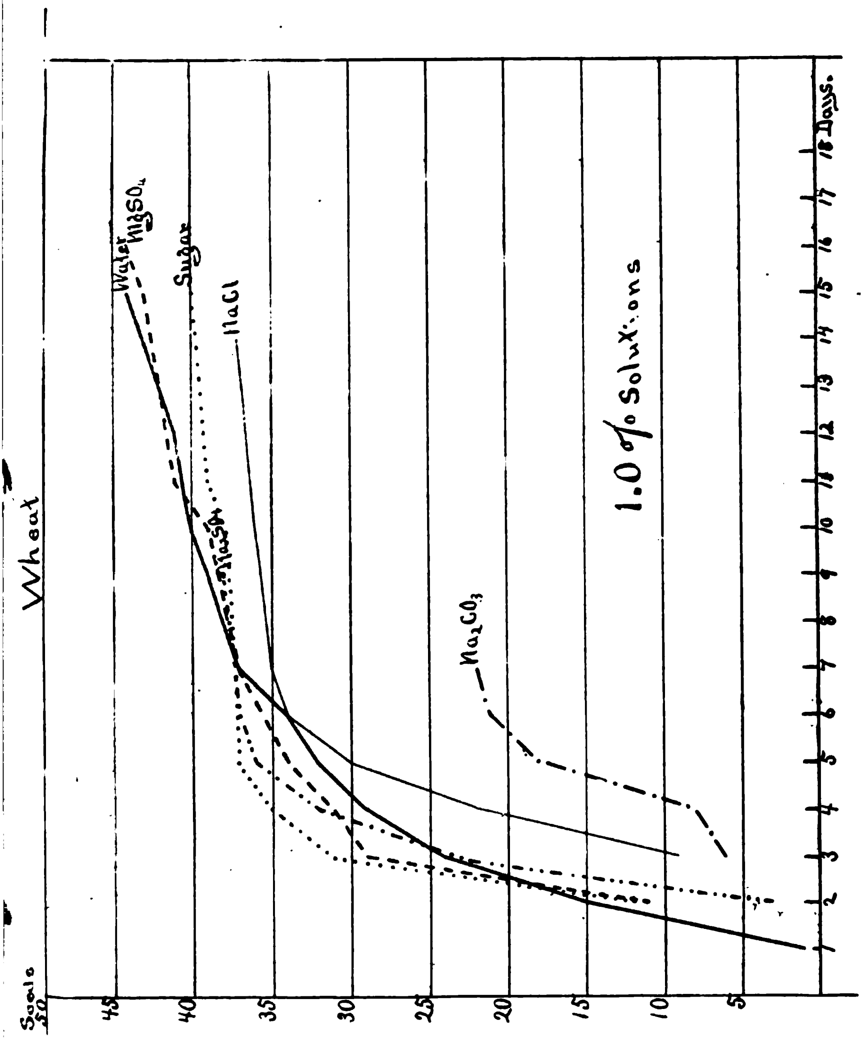

Wheat
1.0 % Solutions
Water
MgSO₄
Sugar
NaCl
Na₂SO₄
Na₂CO₃
Days
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Scale 50
45
40
35
30
25
20
15
10
5

CHART IV.

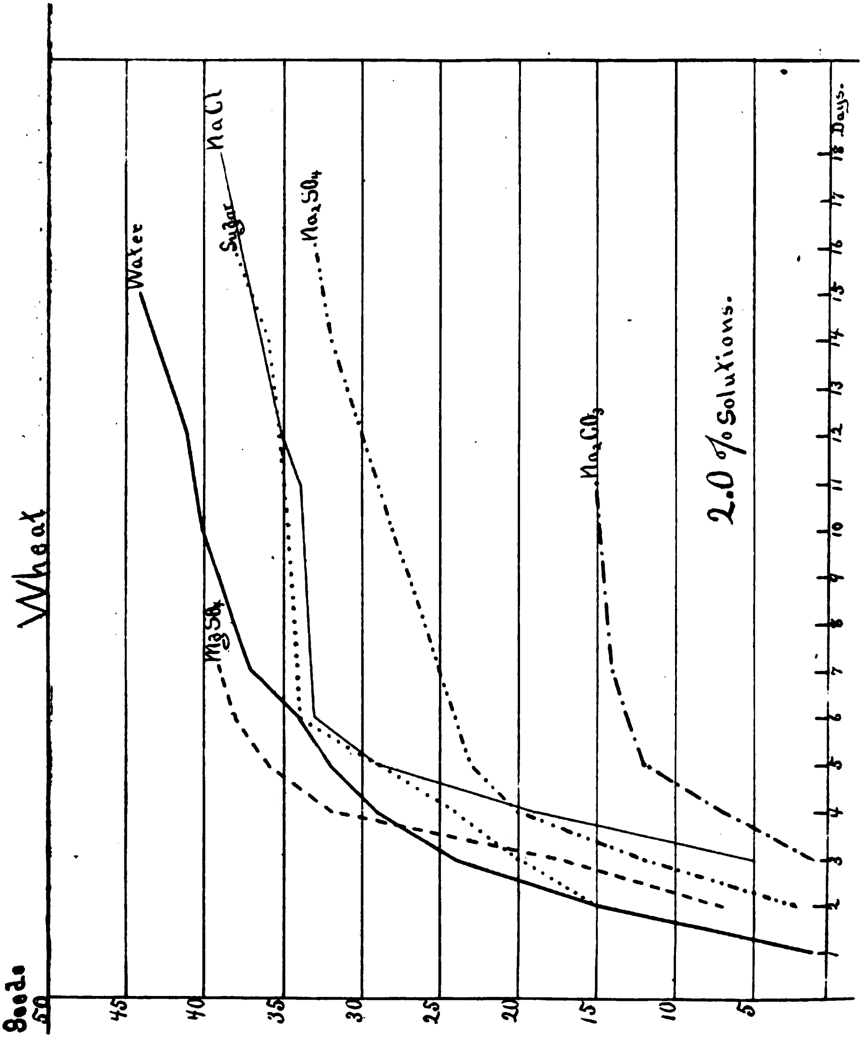

Wheat
2.0 % Solutions.
Water
NaCl
Sugar
Na₂SO₄
MgSO₄
Na₂CO₃
Seeds
50
45
40
35
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18 Days.

CHART V.

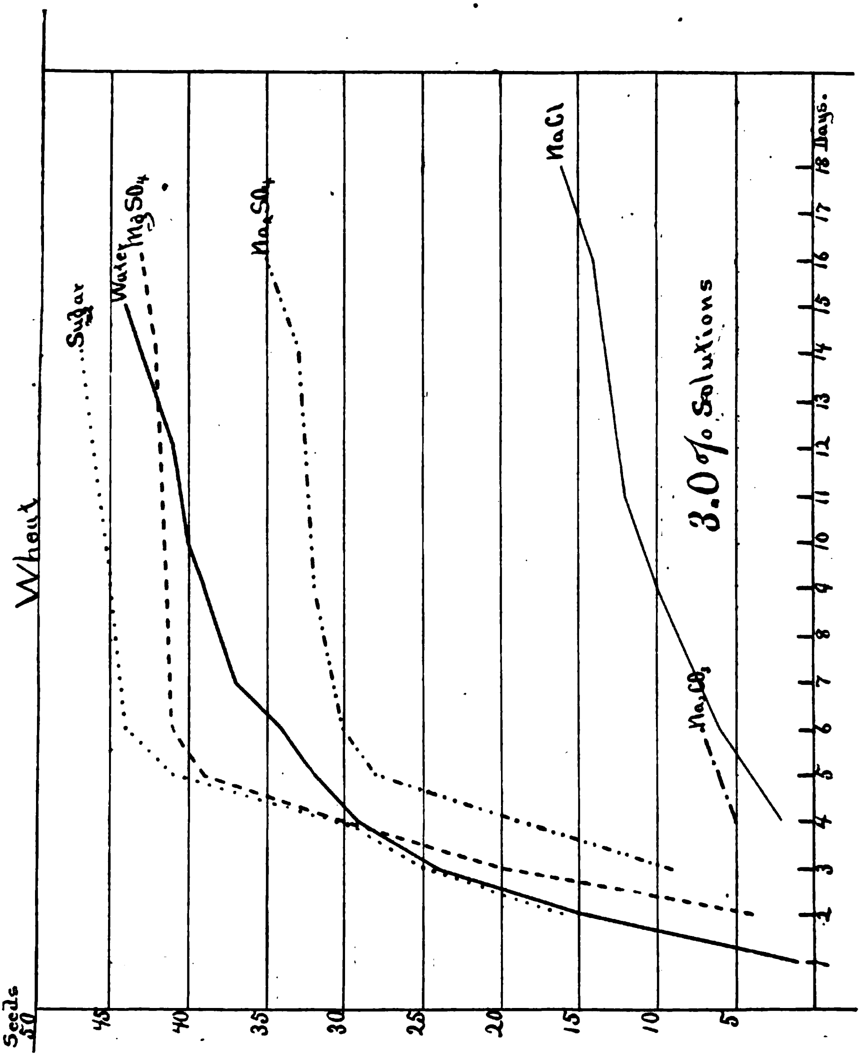

Wheat
3.0% Solutions
Sugar
Water
MgSO4
Na2SO4
NaCl
Na2CO3
Seeds 50
45
40
35
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18 Days.

CHART VI.

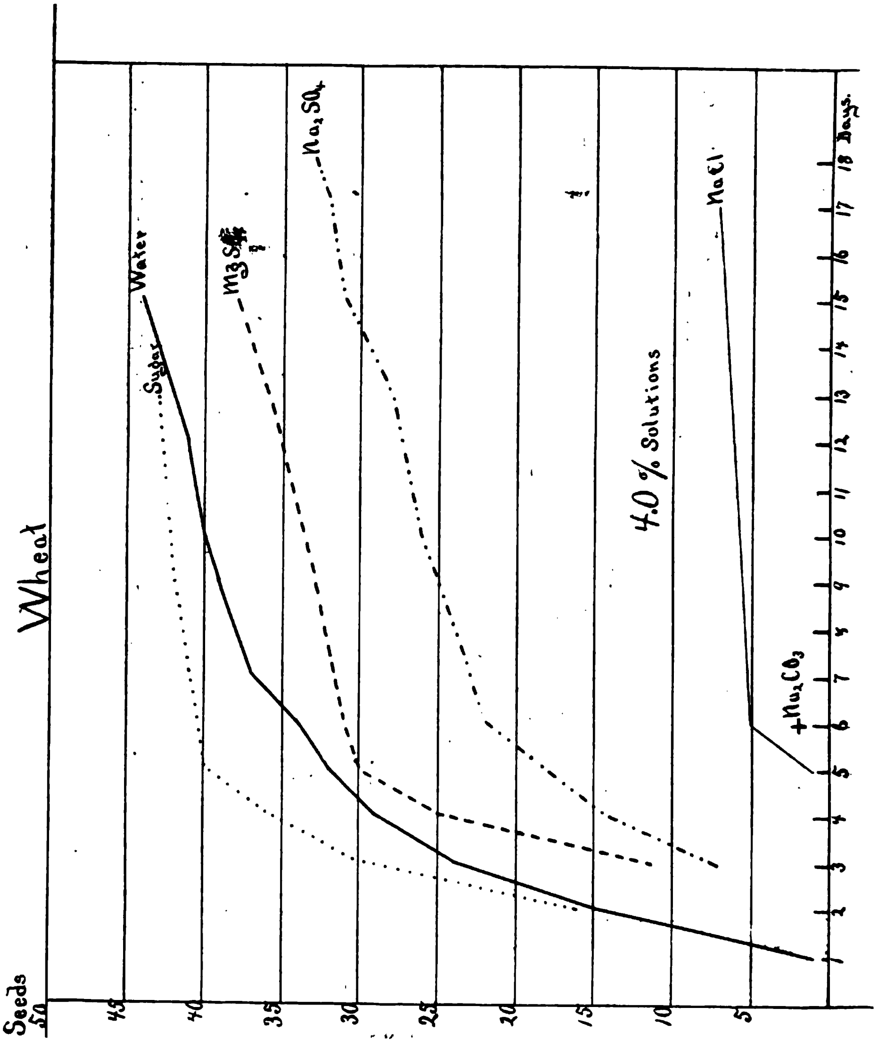

Wheat
4.0 % Solutions
Water
Sugar
MgSO4
Na2SO4
NaCl
+Na2CO3
Seeds
50
45
40
35
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18 Days.

CHART VII.

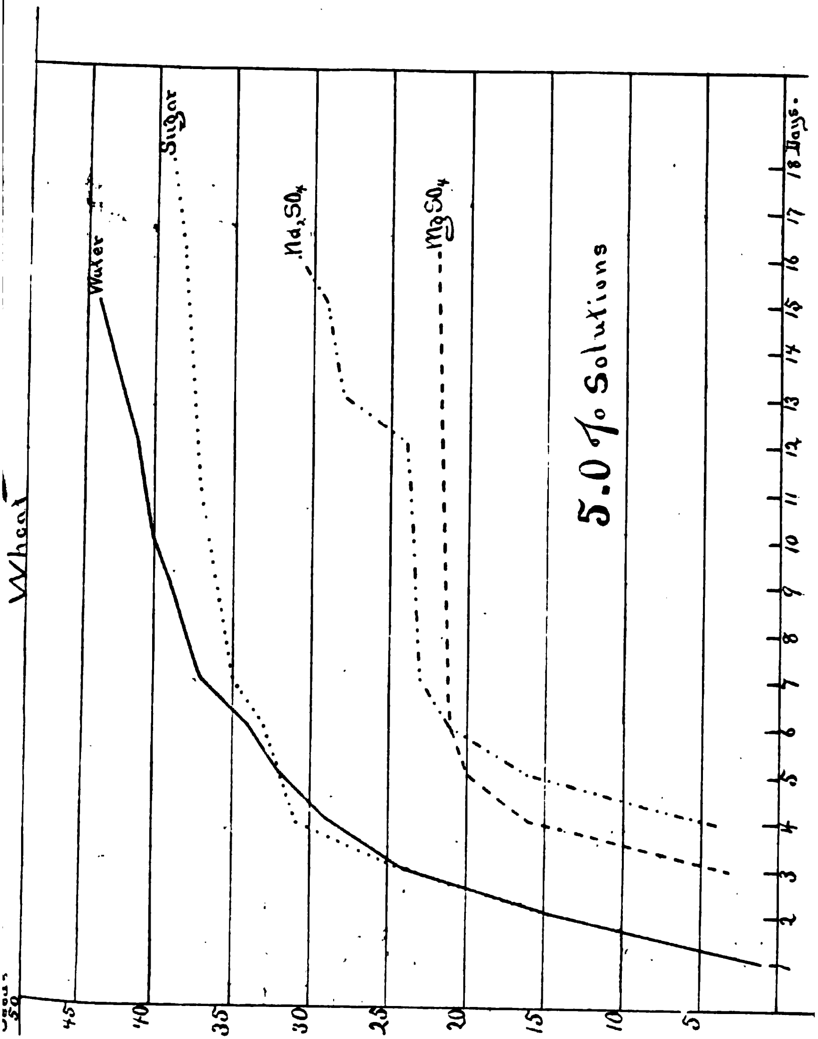

Wheat
Water
Sugar
Na_2SO_4
$MgSO_4$
5.0% Solutions
50
45
40
35
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18 Days.

CHART VIII.

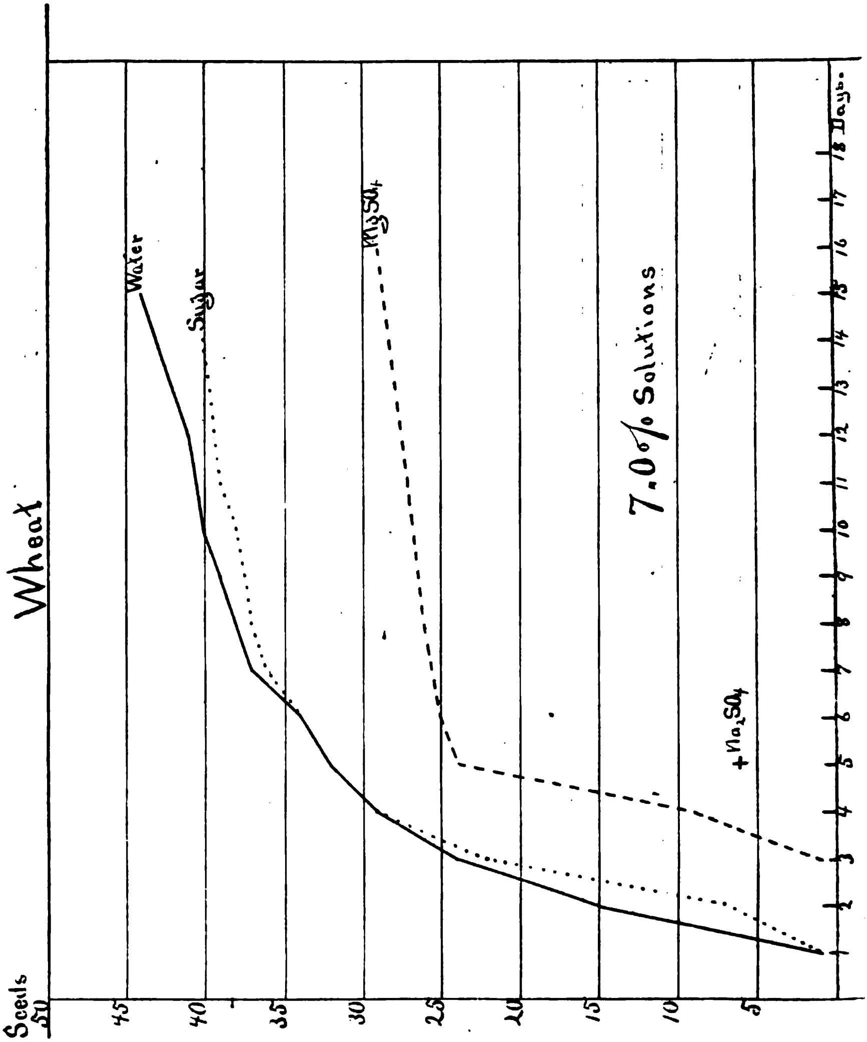

Wheat
7.0% Solutions
Water
Sugar
$MgSO_4$
$+Na_2SO_4$
Seeds
50
45
40
35
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18 Days.

CHART IX.

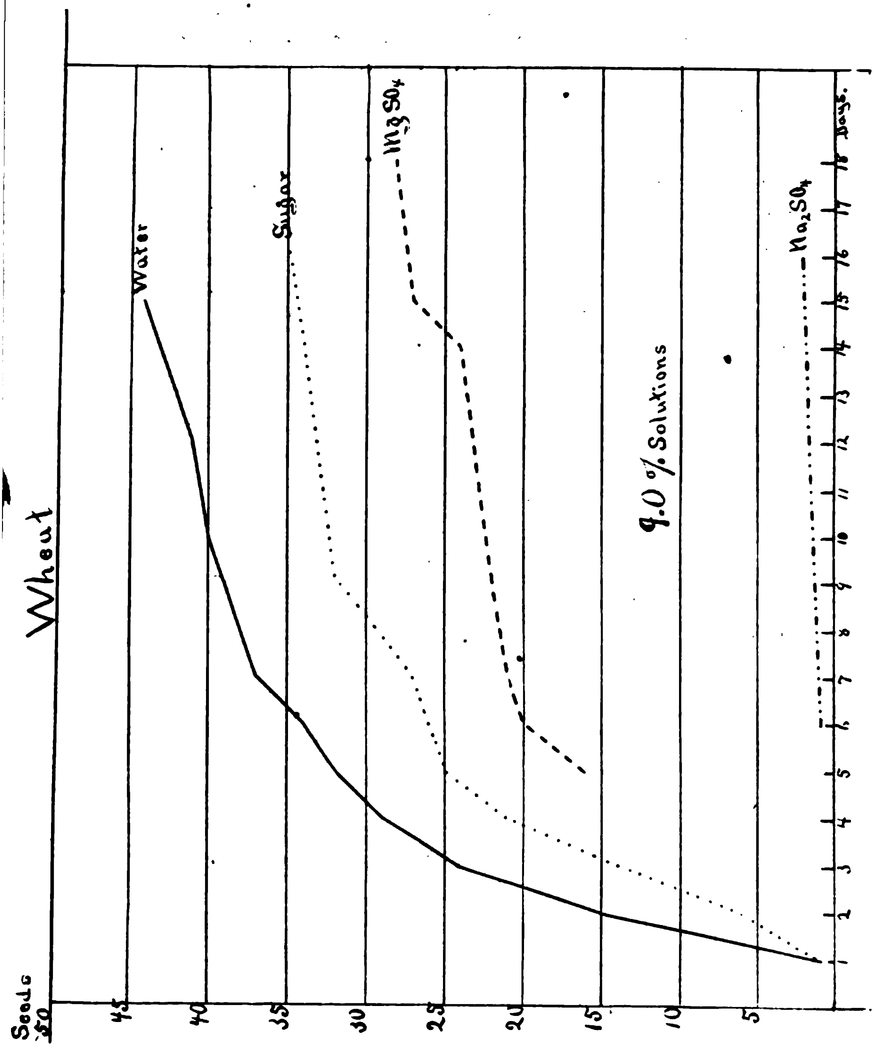

Wheat
9.0 % Solutions
Water
Sugar
$MgSO_4$
Na_2SO_4
Days.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Seeds
50
45
40
35
30
25
20
15
10
5

CHART X.

DESCRIPTION AND RESULTS OF A CHECK TO TEST THE CONCLUSIONS DRAWN FROM THE GERMINATING EXPERIMENTS.

The germinating device used in the foregoing experiments, that is, the method of germinating the seeds between cloths raised slightly above the surface of the solution but with all their edges dipping, is subject to the possible error that, due to the selective absorbtion of the cloth, the solution surrounding the seed may not be the same as the body of the solution. This chance for error was anticipated and once each day, and sometimes more often, the cloths covering the seeds were removed and plunged into their respective solutions. This in all probability practically overcame the influence of the selection which took place during the time the moisture was supplied by capillarity. But to determine the real validity of the results obtained a check test was carried out with the different percents of one of the salts, sodium sulphate, in which the factor just mentioned is eliminated and the seeds were germinated in sand instead of between clothes.

DESCRIPTION OF EXPERIMENT.

Some clean, sharp river sand was obtained and a sufficient quantity was screened through a 1 mm. sieve. The organic matter was removed by allowing 20 liters of 10 per cent hydrochloric acid to leach through it, the sand being first placed in an earthenware vessel with an opening at the bottom. It was then washed for several hours with running water, and finally with distilled water till the chlorides disappeared in the leachings. (The chlorides were not entirely eliminated, as silver nitrates showed the merest trace remaining.) The sand was then dried by heating it for some time in shallow pans to the temperature of boiling or a little above.

Granite-ware plates were used in the test to hold the sand containing the different percents of alkali, 1200 gm. of sand being placed in each. This filled them almost even full, the sand being about seven-eighths of an inch deep. The uper half of this sand was removed and fifty carefully selected seeds of Chili wheat and fifty seeds of Spring rye were placed close together, though not touching on this lower layer of sand. They were then pressed down, with a smooth surface, till their upper edges were even with the level of the sand. It was the original intention to use a flat metal screen to lay over the seeds at this point, covering it with the remaining sand. The seeds would in this way be surrounded by sand and by merely lifting the screen they could readily be examined. A piece of cloth was, however, substituted in place of the metal screen on account of the possibility of the metal rusting or being corroded by the salt and thus adding another factor which might influence the germination. So a piece of fine cheese-cloth with a large mesh was placed over them and the upper layer of sand was carefully poured on. A pane of window glass of suitable size was then placed over each plate to prevent evaporation when the solutions were added. Previous to this a stock solution of 10 percent sodium sulphate had been carefully made up, the salt being heated to a low red heat for a short time, then cooled and weighed.

It was found that 20 percent of moisture added to the sand brought it somewhat near the point of saturation, or to a very desirable condition for the process of germination, so to each plate containing 1200 gm. of sand there was added 300 cc. of solution, this 300 cc. of solution being 20 percent of the sand and water taken together.

In the simple process of germination, the seed is affected only by the salts or substances dissolved in the solution surrounding it. The insoluble material in the soil has mechanical duties, only, to perform. That plants absorb only those substances that are in solution seems so axiomatic that it is scarcely necessary to quote authorities on the point, but Johnson in "How Crops Grow," page 272, says, "The food of the plant, so far as it is derived from the soil, enters it in a state of solution, and is absorbed with the water which is taken up by the rootlets." We have, in an experiment of this kind, therefore, to do with the amount of soluble material with its relation to the amount of water present and *not* with its relation to the amount of soil. This point has apparently been ignored in alkali investigations in general. In the soil analyses the percent of alkali is given but no apparent attention is paid to the amount of moisture in the soil. To arrive at trustworthy conclusions it is highly important that the moisture content be taken into careful consideration, for in the arid regions, where the alkali question becomes a problem, the moisture content varies greatly. The relation of the soil to the amount of salt it may contain is the same no matter how the moisture varies, while it is the variation of the latter which affects the seed or plant. If, for instance, the amount of moisture in the soil changes from 20 percent to 10 percent, the percent of salt in the soil water is doubled, providing the point of saturation is not passed. In that case a part of the salt crystalizes out and becomes as inert as the other insoluble material in the soil. The importance, then, of dealing with the amount of soluble salts in its relation to the amount of soil-water, and not to the total amount of dry soil, is quite apparent.

The 300 cc. of solution, therefore, which was to be added to each 1200 gm. of sand was brought to the required strength by adding enough of the 10 percent stock solution already mentioned, to make it similar to the various solutions used in the previous test where the seeds were germinated between cloths. The strengths of the solutions used are as follows: 9 percent,7 percent,5 percent,4 percent,3 percent, 2 percent, 1 percent, 0.7 percent, 0.4 percent, 0.1 percent. The sand in two plates was wet with distilled water, this making a double check. The seeds being placed in dry sand, no growth would occur till moisture was added. The solutions were added to all the plates within about an hour. The weight of each plate was then carefully taken. For the first few days the plates were weighed, but after allowing for the weight of the seeds which had germinated and been removed, the evaporation was found to be very slight. It was the third day before sufficient loss of weight could be detected to warrant adding water to bring back to the initial weight. At intervals later on water was added when necessary to bring the weights of the plates back to their original weights. The first examination of the seeds occurred 16 hours after the solutions were added; all later examinations occurred about 24 hours apart.

The results of the tests are given in the following tables:

TABLE XI.—*Rye.*

Number of seeds germinated in the different solutions.

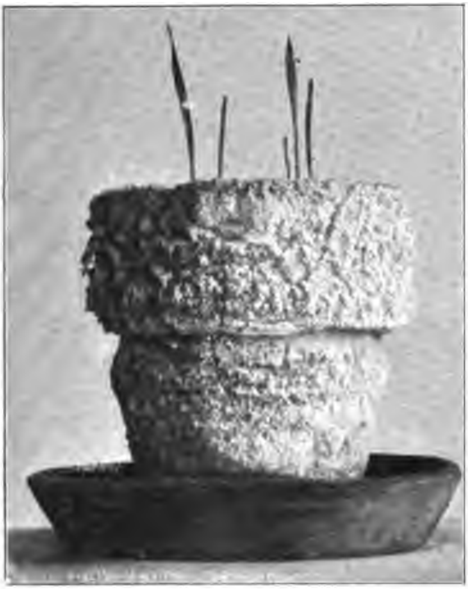
Number of days from beginning of test.	Water.	Water.	Water (average).	0.1 percent.	0.4 percent.	0.7 percent.	1.0 percent.	2.0 percent.	3.0 percent.	4.0 percent.	5.0 percent.	7.0 percent.	9.0 percent.
1	2		(1)			1							
2	44	47	(45)	44	46	42	43	38	34	20	16		
3	48	49	(49)	47	47	49	45	43	44	36	32	1	
4	49						47	44		41	38	8	
5								45			40	15	6
6										42	41	17	13
7							48		45	43			15
8												18	18
9					48					44		20	23
10													
11													
12													
13													
14													
15													25
16													
17													
18													

TABLE XII.—*Wheat.*

Number of seeds germinated in the different solutions.

Number of days from beginning of test.	Water.	Water.	Water (average).	0.1 percent.	0.4 percent.	0.7 percent.	1.0 percent.	2.0 percent.	3.0 percent.	4.0 percent.	5.0 percent.	7.0 percent.	9.0 percent.
1													
2	11	13	(12)	19	8	6	7		1				
3	46	44	(45)	48	46	45	46	36	25	2			
4	47	46	(47)		48	46	47	44	35	20	6		
5	48					48		47	42	29	23	2	
6					49				44	40	31	11	
7									45		33	14	
8									46	41	36	21	1
9										42	39	30	
10	49	47	(48)										2
11												31	4
12													5
13													
14		48										32	9
15													12
16													
17													14
18													16

Comparing the table giving the results with wheat to the table reporting the original test with wheat, found in the first part of this report, where the seeds were germinated between cloths, it will be seen that the seeds planted in sand germinated much more readily and also that a larger part of them germinated than when planted between cloths. That seeds in general act very differently with different germinating devices has been remarked by the late Mr. Hicks of the Department of Agriculture at Washington, D. C., who had wide experience in germinating tests. He says, for instance, that it is with great difficulty that some seeds are germinated between blotters while they germinate readily between cloths whose edges are allowed to dip in water. He says there is no apparent explanation for many of these variations. This general fact doubtless explains why wheat germinated so much more readily when placed in sand than when placed between cloths. With the rye this is not the case, but if anything the reverse, for it will be noted that in



Pot containing 9 percent of Sodium Sulphate, showing incrustation on surface. About one-half natural size.

General view of bench, showing arrangement of pots.

the original experiment, when they were planted between cloths, there were quite a number germinated the first day, in one case as many as 60 percent, while where they were planted in sand scarcely any were germinated, 4 percent being the most in any particular case. This variation one way or the other does not affect the general conclusions that may be drawn, as the results in the respective tests are comparable with each other. So taking each test separately and comparing the number germinated and the rate of germination in the different percents of the salts to the rate, etc., of the germination in the water, we can determine the relative effect of a certain percent of the salt on the germination of the seed.

It is therefore quite apparent that a careful comparison of the tables shows that notwithstanding the variation as to the number germinated and the decided difference in the rate of germination, the percent at which the salt exercises a retarding effect is the same in both experiments.

EXPERIMENT IN GROWING PLANTS IN POTS IN THE PRESENCE OF ALKALI SALTS.

It is probable that definite conclusions cannot be drawn from this experiment in regard to the effect of a given amount of salt on the growth of plants. As the evaporation was so great from the soil surface and from the surface of the porous pots as well, the strength of the salt solution in the soil varied considerably. The effect of this evaporation and the way the salt was carried to the surface of the pots in those containing large amounts of alkali is well shown in the illustration of a pot covered with incrustations of salt. As water was added each day to supply the amount lost by evaporation, this salt was scraped off and washed back into the soil and it is believed the general results in showing the prevention of growth by large amounts of salts are of sufficient value to be published, and the effects produced by the same percents of different solutions are comparable. As would be expected there are wide variations and irregularities in the tables between one strength of solution and the next, but as a whole the experiment shows what may be expected of the different salts and of the quantity present in the soil.

A general view of the pots at the time the seeds were planted is given in the illustration. The plates on the bench back of the pots are as they were used in the first germination experiment which was afterward abandoned and repeated in the manner already outlined.

One hundred and fifty-three two and one-half inch pots were used. Clean river sand was screened through a one millimeter sieve and then put in pans which were placed over the furnaces in the assay department for a few hours. One hundred eighty grams of this sand were put in each pot and these were placed in saucers on the center bench of the greenhouse on moist sand. Each pot had its number placed on it with asphalt varnish. To each pot was added 60 cc. of solution. This contained the required amount of salt and also enough of the salts of the normal nutritive solution, commonly used in water cultures, to make the solutions equal in nutritive value irrespective of the other salts. The normal nutritive solution used is the one given for water cultures in "Frank Lehrbuch der Botanik:"

1.0 g.	$Ca(NO_3)_2$
.25 g.	KCl
.25 g.	$MgSO_4$
.25 g.	KH_2PO_4
1.75 g. in 1000 cc.	H_2O

This was made in more concentrated form and enough added, in making up the 60 cc. of solution each pot was to receive, to make the percent of the nutritive solution the same as in the formula given. This, of course, increased the total percent of salts in the solution 0.175 percent, which is quite a factor in the solutions containing the lower percents of the salts, but in the solutions containing more than one percent of salt this additional amount would not change the results materially. Sixty cc. of solution added to 180 g. of sand would make the percent of moisture in the total amount twenty-five. To every three pots was added the same solution; for example, the first three contained merely water, the second three 0.1 percent sodium chloride, the third three 0.1 pecent sodium sulphate, etc. Five seeds of wheat were planted in the first pot, five of clover in the next, and five of rye in the next. The pots containing wheat were each placed on the balances and small pieces of stone or broken crockery were placed with them to make each weigh 370 g. The pots and weights were then returned to their respective saucers. Every other day at the beginning, and every day in the latter part of the test, these pots were weighed and enough water added to bring them back to their original weight. This amount was measured and recorded and a like amount was added to the clover and rye pots containing identical solutions. After it became evident that the clover seeds would not germinate, the pots in which they were planted were cast out. When the wheat and rye were nicely up the strongest plant in each pot was selected and the others were destroyed, leaving but one plant in each pot.

The test was continued for ninety days, but on the account of the pots being so small it was impossible to keep the sand moist enough, by adding water once a day, to prevent the plants from suffering from lack of it after they had attained a height of ten or more inches. This fact would no doubt vitiate the results, as we have reason to suppose the evaporation from the soil containing a large percent of alkali is less than from soil freer from the salts, for if the plants suffered from lack of moisture, those in large amounts of alkali would probably suffer less from this cause, in consequence of which the results would not be comparable. The results have been tabulated for the first forty days of the test. From the average amount of water added each day during this time to bring the percent of moisture up to twenty-five, it will be seen that the plants in all probability did not suffer for water at any time. On the sides of the pots containing the larger percents of the salts, particularly with sodium sulphate and magnesium sulphate, a white incrustation was formed. This did not accumulate to any extent on the surface of the sand as it was dissolved here when water was added. The incrustation on the outside was scraped into a saucer and from it returned to the pot, where it was soon redissolved. On account of the variation in the concentration of the solutions in the pots, caused by this incrustation, only general conclusions can be drawn from the experiment. The seeds were planted February 7, and in the following tables are given the heights of the plants 16 days later, February 23, and also 40 days later, March 19. The daily average amount of water added, as given in the tables, is the average up to and including March 15. The amount added to the rye is of no particular value as it is the same as that added to the wheat.

From the tables it will be seen that the daily average of water is less in those pots containing the larger percent of salts. The evaporation from a solution containing salt is less than from pure water. It is to be inferred that the reason the pots containing higher percents received less water, was due to this fact and that the evaporation is reduced in soils containing large amounts of alkali. The fact that the plants were not so large in the higher percents, indicates that they absorbed less water, so that the greater loss of moisture from the pots containing lower percents is not due entirely to evaporation from the soil and pot. That the evaporation from soil containing large percents of alkali is less than from soil containing little salt is a matter of common observation and is substantiated by the fact that the evaporation from the pots containing large percents of alkali was less than others during the early part of the test before the plants were up. This point is not brought out in the tables, as only average amounts of water for the time are given. On the pots containing the larger percents of sugar a black fungus formed not only on the surface of the sand but also on the pot. This doubtless affected the evaporation to a marked degree. From the last two tables given it will be seen that a large percent of sodium carbonate has the greatest detrimental effect on the growth of the plants, sodium chloride ranks next, and magnesium sulphate and sodium sulphate have about the same effect. The evaporation in the tables is indicated by the average amount of water necessary to add each day to bring the pots back to their original weight.

TABLE XIII.—*Sodium Chloride.*

Wheat.					*Rye.*			
Number of pot.	Strength of solution.	Evaporation.	Height in 16 days.	Height in 40 days.	Number of pot.	Strength of solution.	Height in 16 days.	Height in 40 days.
	percent	*c. c.*	*inches*	*inches*		*percent*	*inches*	*inches*
1	0.0 (Water)	23	3.5	5.3	3	0.0 (Water)	4.5	7.2
4	0.1	15	3.5	7.5	6	0.1	3.2	5.1
19	0.4	15	3.3	6.0	21	0.4	4.3	9.3
34	0.7	15	3.5	4.3	36	0.7	4.5	6.0
49	1.0	14	4.3	7.4	51	1.0	3.8	4.2
64	2.0	13	3.5	8.7	66	2.0	3.6	6.0
79	3.0	12	2.7	5.3	81	3.0	4.3	5.9
94	4.0	12	1.7	6.4	96	4.0*		
109	5.0	10	not up	4.1	111	5.0	1.3	2.1
124	7.0	11	"	3.4	126	7.0*		
139	9.0	*			141	9.0*		

* Never came up.

TABLE XIV.—*Sodium Sulphate.*

Wheat.					*Rye.*			
Number of pot.	Strength of solution.	Evaporation.	Height in 16 days.	Height in 40 days.	Number of pot.	Strength of solution.	Height in 16 days.	Height in 40 days.
	percent	*c. c.*	*inches*	*inches*		*percent*	*inches*	*inches*
1	0.0 (Water)	23	3.5	5.3	3	0.0 (Water)	4.5	7.2
7	0.1	17	3.6	7.0	9	0.1	4.4	9.2
22	0.4	16	4.4	9.6	24	0.4	5.0	7.3
37	0 7	14	4.1	9.1	39	0.7	2.5	5.9
52	1.0	18	3.4	7.4	54	1.0	3.8	8.3
67	2.0	16	5.5	10.4	69	2.0	4.4	7.9
82	3.0	14	3.3	8.2	84	3.0	3.9	6.2
97	4.0	10	3.9	9.2	99	4.0	4.0	6.3
112	5.0	12	2.7	8.5	114	5.0	3.5	4.6
127	7.0	12	0.2	2.5	129	7.0	3.3	4.5
142	9.0	12	1.1	3.4	144	9.0	2.9	2.1*

* Plant partly dead.

TABLE XV.—*Sodium Carbonate.*

Wheat.					*Rye.*			
Number of pot.	Strength of solution.	Evaporation.	Height in 16 days.	Height in 40 days.	Number of pot.	Strength of solution.	Height in 16 days.	Height in 40 days.
	percent	*c. c.*	*inches*	*inches*		*percent*	*inches*	*inches*
1	0.0 (Water)	23	3.5	5.3	3	0.0 (Water)	4.5	7.2
10	0.1	17	4.4	8.3	12	0.1	4.1	6.3
25	0.4	16	4.2	7.7	27	0.4	4.0	7.2
40	0.7	16	4.1	9.1	42	0.7	4.2	6.8
55	1.0	14	2.5	4.5	57	1.0	3.9	6.6
70	2.0	15	2.3	dead	72	2.0	3.1	dead
85	3.0	14	1.2	"	87	3.0	2.6	"
100	4.0*				102	4.0	2.2	"
115	5.0	13	1.2	"	117	5.0	1.1	"
130	7.0	12	not up	dead†	132	7.0	.5	"
145	9 0*				147	9.0‡		

* Plants were destroyed by mice on the eleventh day.
† Died in two or three days after coming up.
‡ Never came up.

TABLE XVI.—*Magnesium Sulphate.*

Wheat.					*Rye.*			
Number of pot.	Strength of solution.	Evaporation.	Height in 16 days.	Height in 40 days.	Number of pot.	Strength of solution.	Height in 16 days.	Height in 40 days.
	percent	*c. c.*	*inches*	*inches*		*percent*	*inches*	*inches*
1	0.0 (Water)	23	3.5	5.3	3	0.0 (Water)	4.5	7.2
13	0.1	16	3.5	6.4	15	0.1	4.2	6.7
28	0.4	14	4.2	9.4	30	0.4	4.6	6.5
43	0.7	12	4.0	12.2	45	0.7	3.9	6.5
58	1.0	14	3.7	8.1	60	1.0	4.5	7.8
73	2.0	11	3.2	8.8	75	2.0	4.1	6.0
88	3.0	11	4.6	9.6	90	3.0	5.2	9.2
103	4.0	12	4.0	5.2	105	4.0	4.1	5.8
118	5.0	10	3.5	5.4	120	5.0	4.4	5.6
133	7.0	10	3.5	4.5	135	7.0	4.2	3.5*
148	9.0	9	1.0	3.3	150	9.0	4.0	4.5

* Partly dead.

TABLE XVII.—*Sugar.*

Wheat.					*Rye.*			
Number of pot.	Strength of solution.	Evaporation.	Height in 16 days.	Height in 40 days.	Number of pot.	Strength of solution.	Height in 16 days.	Height in 40 days.
	percent	*c. c.*	*inches*	*inches*		*percent*	*inches*	*inches*
1	0.0 (Water)	23	3.5	5.3	3	0.0 (Water)	4.5	7.2
16	0.1	13	4.6	10.0	18	0.1	3.7	5.5
31	0.4	17	4.3	9.1	33	0.4	3.0	5.5
46	0.7	15	3.6	8.3	48	0.7	4.1	7.5
61	1.0	15	3.4	5.5	63	1.0	4.6	7.6
76	2.0	14	3.4	7.5	78	2.0	4.2	6.0
91	3.0	12	3.4	5.0	93	3.0	3.3	4.0
106	4.0	13	3.4	6.2	108	4.0	3.0	3.8
121	5.0	13	3.3	4.8	123	5.0	4.0	5.0
136	7.0	10	3.0	3.5	138	7.0	4.7	4.8
151	9.0	10	2.9	4.1	153	9.0	3.4	3.2*

* Plant partly dead.

TABLE XVIII.—*Rye.*

	0.1 percent.	0.4 percent.	0.7 percent.	1.0 percent.	2.0 percent.	3.0 percent.	4.0 percent.	5.0 percent.	7.0 percent.	9.0 percent.
	inches	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*
Sodium Chloride	5.1	9.3	6.0	4.2	6.0	5.9	†	2.1	†	†
Sodium Sulphate	9.2	7.3	5.9	8.3	7.9	6.2	6.3	4.6	4.5	2.1
Sodium Carbonate. . . .	6.3	7.2	6.8	6.6	*	*	*	*	*	†
Magnesium Sulphate. . .	6.7	6.5	6.5	7.8	6.0	9.2	5.8	5.6	3.5	4.5
Sugar.	5.5	5.5	7.5	7.6	6.0	4.0	3.8	5.0	4.8	3.2

* Dead † Never came up.

TABLE XIX.—*Wheat.*

	0.1 percent.	0.4 percent.	0.7 percent.	1.0 percent.	2.0 percent.	3.0 percent.	4.0 percent.	5.0 percent.	7.0 percent.	9.0 percent.
	inches	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*	*inches*
Sodium Chloride	7.5	6.0	4.3	7.4	8.7	5.3	6.4	4.1	3.4	†
Sodium Sulphate	7.0	9.6	9.1	7.4	10.4	8.2	9.2	8.5	2.5	3.4
Sodium Carbonate . . .	8.3	7.7	9.1	4.5	*	*		*	*	
Magnesium Sulphate . .	6.4	9.4	10.2	8.1	8.8	9.6	5.2	5.4	4.5	3.3
Sugar	10.0	9.1	8.3	5.5	7.5	5.0	6.2	4.8	3.5	4.1

* Dead. † Never came up.

SUMMARY.

(1) The presence of very small amounts of sodium sulphate, sodium chloride, magnesium sulphate or sodium carbonate undoubtedly has a beneficial effect on the germination of seeds and growth of plants. Large amounts of the same salts retard germination.

(2) Of the salts most abundant in the alkali of the arid regions those that have the greatest detrimental effects on germination in order are sodium carbonate, sodium chloride, sodium sulphate, and magnesium sulphate.

(3) The retarding effect of a salt solution on the germination of seeds is in direct proportion to its osmotic pressure, except where other factors enter in, such as the caustic effect of sodium carbonate, or where solutions are very dilute.

ALKALI STUDIES, IV.

By E. E. SLOSSON.

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ALKALI STUDIES, IV.

BY E. E. SLOSSON.

The special subjects to be investigated by an experiment station are largely determined by its location. Unless there is a division of labor among the stations their location in different states gives no advantage to compensate for the disadvantages of isolation and duplication. The Wyoming Station is the only one located on a very high arid plateau, and its work is especially investigation of the problems of agriculture under these conditions which are representative of so much of the Rocky Mountain region. The principal disadvantages of agriculture in such localities are the short and cold growing season, insufficient rainfall, excessive evaporation, and the super-abundance of soluble salts in the soil. Almost all the work of the Wyoming Station since its establishment has had a more or less direct bearing on these subjects and it will be still further coördinated and concentrated in the future.

The disadvantageous conditions of agriculture in these elevated and arid regions can only be overcome in two ways; by changing the conditions where possible or by getting plants to grow under these conditions. As examples of the first line of work may be mentioned irrigation to supplement the rainfall, cultivation of the soil to check evaporation and the removal or dilution of the soluble salts. In the second line of work a good deal has been done in determining what crops will grow in the arid region, but very few attempts have been made in intentional acclimatization of useful plants.

THE ALKALI PROBLEM.

The term "alkali" has by common consent been given to the easily soluble salts of the alkalies and alkaline earths which are found in the soil. The word is misleading, since it conveys the impression that the salts have an alkaline reaction, which is not the case with any of them except sodium carbonate, but as there is no other single word expressing the same idea, there is no reason why it should not be used in scientific as well as popular writing.

It has not been sufficiently understood that the injurious effects of alkali are due to the deficiency of water as much as to the surplus of salts. In the arid region generally the quantity of salts is not so great but that if it were evenly distributed through the soil and diluted with a sufficient amount of water, it would be beneficial rather than harmful. We are not dealing with salts as such, but with salt solutions, which, according to modern chemistry, is an entirely different thing. Whether a certain percentage of salts in the soil is injurious or not depends entirely on the amount of water in the soil. This is quite obvious, yet often overlooked, and we see attempts made to determine the maximum amount of alkali in the soil tolerated by different crops without reference to the water content. Is one-tenth of one percent of sodium sulphate in a soil injurious to wheat? If there is 10 percent of water in the soil it is, if there is 20 percent it is not.* The only statement, then, that can accurately be made, is that a one percent solution of sodium sulphate injures wheat. The importance of this factor may be realized when it is noticed that under irrigation the water content of the soil may change from 5 percent to 25 percent in a few hours.

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*Since the soil is the constant and the moisture the variable it is preferable to base the water content on the dry soil.

In the arid regions, too, it often happens that the soil water is a saturated solution. In such a case, of course, the excess of alkali in the soil is as harmless as sand, and analyses giving large percentages of alkali in soils are misinterpreted unless this is taken into consideration.

THE IMBIBITION OF WATER BY SEEDS.

That seeds do not germinate as early in alkali land as in other is known to every farmer, but the cause has generally been ascribed to some poisonous action of the salts on the living seed. It seemed necessary, therefore, to study the action of salt solutions on seeds, and this subject has been under investigation for three years, with the results here published.

The first thing was to find out whether the seed coating and cell walls were semi-permeable or not; that is, whether they admitted the water more freely than the dissolved salts or whether the solution was absorbed as a whole. If the walls were semi-permeable, the osmotic pressure of the dissolved salt would tend to prevent the imbibition of water and less water would be absorbed from a salt solution than from pure water. An experiment showed that this was the case.* Wheat was weighed and soaked in distilled water and in a 2¼ percent solution of alkali.§

Percentage of Water Absorbed by Wheat	In 24 Hours.	In 96 Hours.
In distilled water	44.2	69.2
In alkali solution	39.9	54.3

This proved that the first deleterious effect of alkali was in hindering the absorption by the seed of sufficient amount of water to germinate. The answer to one question always asks several more, and among those suggested by this experiment were whether osmotic pressure was the important factor, whether there was a difference in the action of different seeds and different salts, whether germination was prevented or merely retarded, whether salts were absorbed at all, and if so, whether they poisoned the seed.

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*Bulletin No. 29, Alkali, by B. C. Buffum, July, 1896; p. 235.

§The composition of the salts selected was the same as that on the Laramie Station Farm.

The experiments were all carried on in the following way. A weighed quantity of seed, about five grams except when they were very small, was put into a wide-mouth two-ounce bottle and covered with a salt solution, the strength of which is determined by titration. Every twelve hours, at 6 A. M. and P. M., the bottles were emptied onto a screen, the seed rolled on sheets of filter paper until superficially dried and then weighed. The fresh solution is poured on each time the seeds are weighed so it remains sufficiently constant in composition. The bottles were kept at room temperature and in diffused light. Slight variations do no harm, because the osmotic pressure of different solutions varies at the same rate except for changes in dissociation. Seeds were counted at beginning and end of the experimnt and somtimes oftener. In the later experiments the volume of the seeds before and after swelling was taken with a specific gravity flask and the chlorides and sulphates in the ash determined.

Many other schemes were tried, especially for drying the seeds, but the above was most rapid and accurate. The variation in weight between two successive dryings is usually less than one-tenth percent but in the case of seeds with somewhat rough coats like sunflower or buckwheat it may amount to five-tenths percent. This is less than the daily variation due to unknown causes. The experiments were stopped when the seeds softened or ceased to absorb water. Since the seeds are completely immersed in water germination does not occur except with a few kinds of seeds and only physical and chemical forces come into play. Seeds in which the power of germination was destroyed by age, heat or formaldehyde gas gave the same results as living seeds.

IMBIBITION OF WATER FROM ONE PERCENT SALT SOLUTIONS.

In Table I are given the results of soaking wheat, clover and rye in solutions of one percent of the common alkalies, sodium chloride, sulphate and carbonate, and magnesium sulphate. A solution of cane sugar of the same strength is included as this is not ionized and cannot be supposed to injure the seed by chemical action. The osmotic pressure is calculated from the formula[*] $P=\frac{.0819\,T}{V}\left(1+\frac{c\,(n-1)}{C}\right)$ in which P is the osmotic pressure in atmospheres, T is the absolute temperature, V is the volume in liters which contains one gram-molecule of the salt, c is the electrical conductivity of the solution, C is the electrical conductivity at indefinite dilution,[§] and n is the number of ions into which the molecule dissociates. The osmotic pressure of sodium carbonate is not exact because the extent of hydolytic dissociation is not known.

The clover seed began to break open almost from the first and had to be abandoned. The sugar solution, of which the osmotic pressure is insignificant, would be expected to give the same results as water. In both cases however the imbibition is greater than from pure water. This may be due to an accumulation of sugar in the seed increasing its weight but it will be noticed in many places in the following tables that seeds imbibe more and germinate better in a solution of either sugar or salts with a slight osmotic pressure than in water alone and it appears that distilled water is not as favorable for germination as solutions like ordinary soil water.

In all cases the imbibition from salt solutions is decidedly less than from pure water. In the tests on wheat the amount of water absorbed decreases as the osmotic pressure increases with the exeception of sodium carbonate solution, the action of which is irregular in all

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[*] Nernst: Theoretical Chemistry, p. 137.

[§] The conductivities were taken from Smithsonian Physical Tables, p. 290, and Ostwald: Lehrbuch der allgemeinen Chemie, 11, 2, p. 723.

TABLE I—*Imbibition of Water from One Per Cent Salt Solutions.*

No.	Kind of Seed	Solution of	Osmotic Pressures, Atmospheres	PERCENTAGE OF WATER ABSORBED.														
				12 hours	24 hours	36 hours	48 hours	60 hours	72 hours	84 hours	96 hours	108 hours	120 hours	132 hours	144 hours	156 hours	168 hours	180 hours
1	Wheat	Pure water	0	30.3	46.4	50.2	54.6	57.6	60.8	63.4	64.6	66.0	68.2	68.0	69.4	70.4	70.2	70.2
2	Wheat	Sugar	.7	31.6	45.4	52.4	57.0	60.4	63.0	65.6	66.8	68.4	71.2	71.5	73.3	73.8	73.6	74.0
3	Wheat	Sodium Sulphate . .	3.9	28.4	41.4	46.2	49.6	51.8	53.8	55.0	55.8	56.4	58.8	58.6	58.9	60.2	60.6	60.8
4	Wheat	Sodium Chloride . .	7.4	26.5	39.8	44.2	47.2	49.8	51.8	53.2	53.2	53.2	54.2	53.6	54.0	54.0	54.0	54.4
5	Wheat	Sodium Carbonate .	4.3	29.1	43.1	47.5	50.5	53.9	55.4	57.6	57.6	58.6	61.0	61.4	63.0	63.0	63.2	63.4
6	Wheat	Magnesium Sulphate	2.8	28.7	42.5	48.1	50.5	54.1	56.1	58.5	59.5	59.5	61.2	62.4	64.0	64.3	64.3	64.3
7	Rye	Pure Water	0	31.7	52.1	59.7	66.3	73.3	78.7	82.5	85.6	88.8	92.2	93.8	94.6	95.2	94.6	95.0
8	Rye	Sugar	.7	32.7	51.9	60.3	67.3	73.9	79.1	83.0	88.4	91.5	94.8	96.8	99.8	100.5	100.7	100.9
9	Rye	Sodium Sulphate . .	3.9	31.2	47.2	55.2	60.0	65.4	69.8	72.8	74.4	76.8	79.0	79.8	80.4	80.8	81.0	81.2
10	Rye	Sodium Chloride . .	7.4	30.0	46.2	53.8	59.6	65.2	69.0	71.8	74.0	74.8	76.6	79.6	80.0	80.2	80.8	81.2
11	Rye	Sodium Carbonate .	4.3	30.2	46.5	54.7	60.7	65.5	69.1	71.3	71.9	73.1	74.9	75.7	75.7	76.7	77.1	77.5
12	Rye	Magnesium Sulphate	2.8	29.5	45.8	54.4	60.0	63.6	68.1	70.9	73.5	72.7	73.3	76.3	78.3	78.3	78.3	78.7
13	Clover	Pure Water.	0	1.9	5.5	5.5												
14	Clover	Sugar	.7	1.4	3.7	3.7												
15	Clover	Sodium Sulphate . .	3.9	3.9	4.4	3.9												
16	Clover	Sodium Chloride . .	7.4	.9	2.5	.9												
17	Clover	Sodium Carbonate .	4.3	3.4	2.4	1.4												
18	Clover	Magnesium Sulphate	2.8	.0	1.4	1.9												

experiments, doubtless on account of its caustic effect. In rye all the salts retard imbibition, but not in proportion to their osmotic pressure. Apparently rye is less affected by differences in alkali than wheat and this is confirmed by the germination tests. It will be noticed that more water is imbibed by rye than wheat.

IMBIBITION OF WATER BY WHEAT.

In the next experiment wheat was chosen as the seed tested and isomotic solutions of the common alkalies were made up together with a sugar solution of the same osmotic strength for comparison. The results are given in Table II.

It will be seen that the amount of water imbibed from isosmotic solutions is nearly the same regardless of the kind of substance dissolved. A difference of one atmosphere osmotic pressure decreased the amount of water absorbed by an average of 1.3 percent and ten atmospheres decreases it by 14.0 percent. Many cultivated soils in the arid region contain sufficient salts to give a pressure of ten atmospheres opposing the entrance of water into the seeds.

Solutions of sodium chloride were also used running up to one hundred atmospheres calculated pressure. It appears that when concentrated solutions are used an increase in the amount of the salt does not produce its proportional effect. That is, a small amount of alkali makes a decided difference in the water imbibed but any additional salt does not make it much worse. One hundred atmospheres pressure shows a diminution of 29.23 percent, about twice the effect produced by ten atmospheres. The irregularities in the strong solutions are also very great, for example more water is imbibed against 50 atmospheres than against 40.

The actual pressure tending to prevent the absorption of water by the seed is not nearly so great as the numbers indicate for two reasons. One is that the formula only applies to dilute solutions and the osmotic pressure becomes less than the theoretical with increasing concentration, just

TABLE II —*Imbibition of Water by Wheat From Solutions.*

No.	Solution	Strength per cent	Osmotic Pressure, Atmospheres	PERCENTAGE OF WATER ABSORBED.												Pure Water Absorbed, per cent.
				12 hours	24 hours	36 hours	48 hours	60 hours	72 hours	84 hours	96 hours	108 hours	120 hours	132 hours	144 hours	
1	Pure Water.	0	0	33.1	42.6	49.2	51.6	54.6	53.7	58.3	60.1	60.1	61.7	62.3	62.3	
2	Sugar	1.43	1	33.4	43.2	49.3	51.3	54.3	55.2	58.2	59.8	60.8	61.4	62.0	61.7	
4	Magnesium Sulphate	.34	1	31.4	40.1	46.3	49.3	52.1	54.7	56.7	57.7	59.6	60.6	60.8	60.2	
6	Sodium Sulphate	.24	1	32.1	41.6	47.8	48.8	53.2	54.4	57.7	58.3	60.1	61.9	61.7	60.7	
8	Sodium Chloride	.12	1	34.0	41.9	49.5	50.0	51.8	53.7	56.9	57.9	58.3	59.1	59.3	60.3	
3	Sugar	14.30	10	26.4	27.9	41.8	44.2	45.0	46.0	46.7	47.8	48.1	48.1	48.1	47.9	
5	Magnesium Sulphate	3.94	10	31.2	38.4	43.3	45.5	45.9	46.9	47.9	48.9	48.9	48.9	48.7	47.7	
7	Sodium Sulphate	2.66	10	29.7	38.3	43.6	44.0	45.1	45.9	46.3	47.9	48.3	48.6	48.3	49.2	
10	Sodium Chloride	1.39	10	31.5	39.7	44.3	44.9	46.6	47.0	47.2	47.2	47.6	47.4	48.2	50.0	
9	Sodium Chloride	.67	5	29.6	38.0	42.6	43.4	45.0	47.4	49.6	51.4	51.1	51.4	52.4	53.8	
11	" "	2.83	20	28.7	37.6	41.9	43.4	44.2	45.0	45.8	46.2	46.6	46.2	46.4	47.1	
12	" "	4.34	30	25.4	35.7	38.2	40.3	41.6	42.2	42.6	43.1	44.1	43.5	43.9	44.1	43.1
13	" "	5.86	40	24.8	32.7	38.0	38.9	40.5	40.9	41.2	41.4	41.3	41.3	41.8	42.4	41.2
14	" "	7.56	50	20.8	28.7	34.4	35.4	38.0	39.4	40.0	40.4	41.0	41.0	41.8	43.4	41.5
15	" "	9.29	60	20.8	27.2	32.5	33.6	35.4	36.9	37.7	38.1	38.1	38.5	39.8	40.4	37.9
16	" "	11.00	70	17.8	24.9	29.6	32.3	32.3	33.7	35.1	35.9	36.7	36.8	37.9	39.1	37.7
17	" "	12.72	80	18.4	25.0	28.9	31.1	31.9	33.4	34.8	35.8	36.8	36.7	37.5	38.3	35.4
18	" "	14.44	90	18.7	23.0	27.4	30.3	32.4	33.5	35.5	36.1	37.1	36.9	37.9	39.1	35.9
19	" "	16.16	100	13.3	20.6	25.6	29.0	32.2	32.4	35.4	36.3	37.7	37.9	37.7	38.3	33.1

as Boyle's law does not give correct results for condensed gases. The correction for this is not known, however, so the theoretical numbers are given. Another point that must be taken into consideration is that the seed is not semi-permeable in the technical sense. Salt is absorbed along with the water although not in the same proportion. The amount of salt absorbed by the wheat was determined in some of the samples by incineration and titration and the quantity is given in Table III, column five. The weight of grain taken is about five grams. In the next column the same thing is given in percentages, and represents the number of grams of salt absorbed by 100 grams of wheat under the stated osmotic pressure. To ascertain how the strength of the salt solution inside the seed compared with that outside, the percentage of salt was calculated on the total amount of water in the wheat, this amount being found by adding to the water absorbed, the water originally in the seed, which is about 10 percent.* This compared with the third column shows the relative concentrations of the salt solutions outside and inside the seed, assuming of course that all the salt absorbed is held in solution. Calculating the osmotic pressure inside the grain due to the salt with that of the solution outside gives column 8, the real osmotic pressure tending to prevent the imbibition of water. The osmotic pressure of the solution inside the grain due to other substances than the salt absorbed is of course not known. With increasing concentration the amount of salt absorbed with the water continually increases although not in the same proportion, so the net osmotic pressure also rises. From 50 atmospheres upward the true osmotic pressure is about half the theoretical. This net osmotic pressure is, however, not exerted during the whole experiment but is only that at the end. The salt is absorbed gradually and accumulates so the inhibiting osmotic pressure is slowly and continuously

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*Koenig: Nahrungs-und Genussmittel, I, 471.

TABLE III.—*Effect of Solutions on Wheat.*

No.	Solution.	Strength per cent.	Osmotic Pressure, Atmospheres	Sodium Chloride in Soaked Seed.		Percentage of salt in water in wheat.	Net Osmotic Pressure, Atmo pheres.	Volume before soaking, c. c.	Volume after soaking, c. c.	Increase in volume, per cent.	Specific gravity before soaking.	Specific gravity after soaking.
				Grams.	Per cent. of dry weight							
2	Sugar	1.43	1	.0022	.04	. .	. .	3.90	6.98	78	1.29	1.22
3	Sugar	14.30	10	. . .	. .	. .	. .	3.91	6.56	67	1.29	1.20
8	Sodium Chloride	.12	1	.0013	.03	.03	.7	. .	. .	. .	1.29	. .
9	" "	.67	5	.0017	.03	.05	4.6	. .	. .	. .	1.29	. .
10	" "	1.39	10	.0088	.17	.25	8.0	. .	. .	. .	1.29	. .
11	" "	2.88	20	.0224	.43	.76	14.0	. .	. .	. .	1.29	. .
12	" "	4.34	30	.0545	1.07	2.00	15.8	3.92	6.22	58	1.29	1.23
13	" "	5.86	40	.0620	1.20	2.20	24.5	3.90	6.07	52	1.29	1.27
14	" "	7.58	50	.0946	1.87	3.50	25.6	3.91	6.06	55	1.29	1.26
15	" "	9.20	60	.1188	2.44	4.84	26.7	3.75	5.84	55	1.29	1.23
16	" "	11.00	70	.1513	3.07	6.25	27.7	3.81	5.66	48	1.29	1.28
17	" "	12.72	80	.1421	2.91	6.02	39.1	3.76	5.58	47	1.29	1.28
18	" "	14.44	90	.1636	3.25	6.58	45.8	3.80	5.53	44	1.29	. .
19	" "	16.16	100	.2675	5.31	11.00	30.0	. .	. .	. .	1.29	. .

reduced. It will be seen accordingly from Table II that the salt in solution exerts a greater influence at first than afterwards. At the end of twenty-four and thirty-six hours the series is more regularly in inverse proportion to the osmotic pressure than later. The ratio of the amounts of water absorbed remains nearly constant throughout. At thirty-six hours the wheat in the 100 atmosphere solution had absorbed 52.0 percent of the amount absorbed by that in pure water and at 144 hours 53.1 percent. Evidently then the presence of salts in solution retards more than it prevents the imbibition.

The figures given in Table II are strictly speaking the total increase of weight and include the salt as well as the water absorbed. In the last column of this table the final figures are corrected by substracting the weight of the salt absorbed and they are more regular than the uncorrected percentages.*

The volume of the soaked wheat is reported in Table III in comparison with the original volume of the wheat as calculated from the specific gravity determination on a single sample. The increase in volume varies inversely with the osmotic pressure like the increase in weight.

IMBIBITION OF WATER FROM SALT SOLUTIONS BY VARIOUS SEEDS.

To see how great a difference there was in the behavior of different kinds of seeds a series of tests were run with sunflower, peas, buckwheat, rape and Scirpus paludosus, each in pure water and in solutions of sodium chloride of five and ten atmospheres osmotic pressure. Scirpus paludosus is a native plant that grows readily in strong alkali ground.

As Table IV shows, the presence of salts in solution diminished the amount of water absorbed in all cases except No. 3, sunflower, which shows a surprising variation from

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*Part of this table was published in Bull. No. 39, where, however, the heading should be "Parts per Thousand" instead of "Percent".

TABLE IV.—*Imbibition of Water From Salt Solutions by Various Seeds.*

No.	Kind of Seed.	Per cent. of Sodium Chloride.	Osmostic Pressure, Atmospheres.	PERCENTAGE OF WATER ABSORBED.													
				12 hours	24 hours	36 hours	48 hours	60 hours	72 hours	84 hours	96 hours	108 hours	120 hours	132 hours	144 hours	156 hours	192 hours
1	Sunflower	0	0	83.4	95.5	110.2	115.4	121.3	126.8	131.4	132.7	138.0	137.8	136.9	137.1		
2	"	.67	5	74.3	89.2	90.2	103.8	110.6	113.6	122.1	127.3	129.8	131.1	131.1	131.0		
3	"	1.39	10	71.7	92.9	116.4	120.0	126.0	136.5	144.0	148.3	154.0	156.5	160.1	161.2		
4	Peas	0	0	82.4	91.0	98.2	101.4	104.2	108.3	110.1	110.8	117.0	117.3	120.1			
5	"	.67	5	68.8	76.1	80.1	83.3	85.6	89.9	92.2	93.2	95.0	96.9	100.6			
6	"	1.39	10	76.8	83.8	87.9	89.5	91.8	93.3	94.6	95.6	96.5	97.6	99.6			
7	Buckwheat	0	0	45.0	53.4	56.5	59.9	65.2	64.1	64.5	65.7	65.5	65.4	65.8	65.8	64.6	64.8
8	"	.67	5	42.0	44.8	46.7	48.4	53.8	52.8	53.4	54.0	53.8	52.8	53.8	53.4	53.2	54.0
9	"	1.39	10	39.9	43.3	46.3	47.3	49.8	50.5	51.1	51.3	52.5	50.1	50.5	50.7	50.9	50.7
10	Rape	0	0	53.7	54.7	56.7	57.0	57.7	58.3	59.0	60.0	63.0	58.3	58.3	57.7	57.3	
11	"	.67	5	48.7	49.0	51.0	50.7	50.7	50.7	51.3	52.7	53.0	49.7	49.7	50.0	50.3	
12	"	1.39	10	45.7	47.0	49.0	47.7	50.3	50.3	50.3	50.3	50.3	47.7	49.3	47.3	48.3	
13	Scirpus	0	0	23.3	23.3	27.0	28.3	31.0	30.6	32.0	32.3	33.3	30.3	32.3	31.6	32.0	32.6
14	"	.67	5	17.3	22.0	27.0	27.6	30.0	30.6	31.3	31.3	31.3	31.3	31.3	31.6	32.3	32.2
15	"	1.39	10	16.0	22.3	25.3	27.0	27.6	28.6	29.6	29.6	29.6	29.6	30.0	30.0	30.0	30.0

TABLE V.—*Effect of Sodium Chloride Solutions on Various Seeds.*

No.	Kind of Seed.	Percentage of salt in solution.	Osmotic Pressure, Atmospheres.	Salt in soaked seed Percentage on dry weight.	Percentage of salt in water in seed.	Net Osmotic pressure, Atmospheres.	Volume before soaking, c. c.	Volume after soaking, c. c.	Increase in volume, per cent.	Specific gravity before soaking.	Specific gravity after soaking.
1	Sunflower	0	0	.044	.03	.2	8.75	10.88	24.4	.575	1.055
2	"	.67	5	.155	.11	4.0	8.71	10.83	24.3	.575	1.059
3	"	1.39	10	.451	.27	8.1	8.78	12.43	41.5	.575	1.057
4	Peas	0	0	.044	.03	.2	3.76	10.34	175.0	1.326	1.067
5	"	.67	5	.506	.44	2.0	3.86	10.20	164.2	1.326	1.009
6	"	1.39	10	1.309	1.16	2.0	4.03	10.43	158.7	1.326	1.029
7	Buckwheat	0	0	.014	.02	.1	4.36	6.74	54.6	1.154	1 216
8	"	.67	5	.016	.03	4.8	4.35	6.41	47.4	1.154	1.243
9	"	1.39	10	.016	.03	9.8	4.33	6.33	46.0	1.154	1,191
10	Rape	0	0	.010	.02	.1	2.82	4.54	61.0	1.066	1.071
11	"	.67	5	.026	.04	4.8	2.82	4.33	53.6	1.066	1.076
12	"	1.39	10	.073	.13	9.1	2.82	4.32	53.1	1.066	1.077
13	Scirpus	0	0	.017	.05	.3	3.98	5.18	30.1	.753	.766
14	"	.67	5	.043	.12	4.2	3.98	4.66	17.0	.753	.859
15	"	1.39	10	.070	.20	8.6	4.74	5.34	31.2	.753	.729

what was expected. In Table V are given other data from this experiment which show that all kinds of seeds absorb more salt from strong than from weak solutions so that the real osmotic pressure is somewhat reduced. This is very slight except in the case of peas, which admit the salt almost as freely as the water so that the net osmotic pressure is reduced almost to zero. Peas in five and ten atmosphere solutions absorbed practically the same amount of water and the net osmotic pressure is really the same. All the seeds except peas will grow well in alkali land. Scirpus is a native alkali plant and the Russian sunflower has been recommended for cultivation because of its immunity from the effects of alkalia. The rape and Scirpus seeds are somewhat alike in size and appearance and practically absorbed no more water after the fourth day. Sunflower and peas began to sprout at the end of the experiment. The volume and specific gravity determinations are of little interest. The percentages of salt in the seeds after soaking in the distilled water given in the table are always less than in the original seed, showing that some of the salts had been washed out. The percentages of water in the original seed used in calculating column 6 of Table V are taken from Keonig as follows: Buckwheat 14 percent, rape 7 percent, sunflower 8 percent, peas 14 percent, corn 9 percent.

IMBIBITION OF WATER FROM SALT SOLUTIONS BY CORN AND WOOD.

An experiment on sweet corn with five isosmotic solutions of the common alkalies and sugar gave the same results as were obtained before on other seeds. (Tables VI and VII.) In all cases five and ten atmospheres osmotic pressure diminishes the amount of water absorbed. A double check was run in pure water which shows that the difference between different seeds due to surface and structure is considerable. The irregularity due to this cause is greater with corn when the five grams contained only

TABLE VI.—*Imbibition of Water From Salt Solutions by Corn and Wood.*

No.	Substance used	Solution of	Strength of solution, per cent.	Osmotic pressure atmospheres	PERCENTAGE OF WATER ABSORBED.												
					12 hours	24 hours	36 hours	48 hours	60 hours	72 hours	84 hours	96 hours	108 hours	120 hours	132 hours	144 hours	156 hours
1	Corn	Pure Water.	0	0	47.5	64.6	78.0	85.0	92.3	97.3	101.1	103.5	104.3	105.5	106.0	106.3	106.5
2	"		0	0	49.2	66.6	79.2	85.4	92.1	96.2	100.0	102.4	104.4	105.1	106.1	105.9	105.7
3	Corn	Sugar.	7.2	5	45.0	58.5	69.1	73.9	77.7	79.7	82.0	83.3	84.5	85.2	84.5	83.7	82.4
4	"		14.3	10	38.6	52.7	61.5	65.8	69.8	71.7	73.7	74.8	74.6	74.8	74.0	73.1	71.9
5	Corn	Magnesium Sulphate	1.85	5	46.1	62.9	75.1	80.6	85.3	90.7	92.2	94.3	96.5	97.7	98.5	99.5	97.7
6	"		3.94	10	39.1	52.3	64.7	69.2	73.7	78.4	80.1	81.6	83.6	84.8	85.3	85.7	85.5
7	Corn	Sodium Sulphate	1.23	5	46.1	63.5	77.5	81.5	87.6	92.2	93.5	96.9	98.9	98.9	96.7	96.5	94.9
8	"		2.86	10	43.7	58.8	70.2	75.9	81.4	84.5	88.6	90.2	91.4	92.5	92.2	93.5	93.1
9	Corn	Sodium Carbonate	1.34	5	54.5	59.9	81.5	86.0	90.3	92.8	95.8	97.4	99.6				
10	"		3.87	10	48.5	63.0	72.6	76.6	79.2	80.6	80.6	81.7	83.0				
11	Corn	Sodium Chloride.	.67	5	45.6	60.6	71.8	79.4	85.8	90.0	89.8	96.4	98.8	99.6	99.8	99.6	99.8
12	"		1.39	10	39.9	55.9	65.4	70.2	75.8	79.2	80.7	84.7	86.3	87.5	88.1	88.3	89.1
13	"		2.83	20	39.3	52.8	63.7	68.9	74.1	78.4	82.8	85.6	88.6	90.4	92.0	93.4	95.0
14	"		4.34	30	35.0	46.5	54.8	59.2	63.6	66.9	70.4	72.9	75.6	77.9	79.6	81.5	82.5
15	"		5.86	40	29.6	38.1	46.5	50.7	55.9	59.3	64.0	67.9	72.2	73.0	75.1	77.3	79.7
16	"		7.58	50	26.6	37.6	45.5	49.4	55.9	60.2	65.1	69.0	71.9	76.9	79.8	83.3	86.9
17	Wood	Pure Water.	0	0	55.5	64.6	76.1	79.7	80.1	88.5	92.9	96.5	102.8	107.3	113.4	117.3	122.2
18	"	Sodium Chloride	1.39	10	53.2	60.8	69.8	72.7	77.7	78.8	83.5	86.9	92.6	96.1	101.7	105.1	100.5

TABLE VII.—*Effect of Salt Solutions on Corn and Wood.*

No.	Substance used	Solution of	Strength, per cent.	Osmotic pressure atmospheres.	Salt after Soaking. Per cent of dry weight.			Percentage of salt in water absorbed.	Net osmotic pressure, atmospheres.	Volume before soaking, c. c.	Volume after soaking, c. c.	Increase in volume, per cent.	Specific gravity before soaking.	Specific gravity after soaking.
					Magnesium Sulphate.	Sodium sulphate	Sodium chloride.							
1	Corn	Pure water	0	0						4.42	10.57	139	1.138	1.085
2	"	Pure water	0	0						4.77	10.33	116	1.138	1.093
3	"	Sugar	7.2	5						4.64	9.10	96	1.138	1.068
4	"	Sugar	14.3	10						4.57	8.40	84	1.138	1.076
5	"	Magnesium Sulphate	1.85	5	.19			.19	4.5	4.48	9.34	108	1.138	1.087
6	"	Magnesium Sulphate	3.94	10	.48			.46	8.8	5.03	9.76	94	1.138	1.098
7	"	Sodium Sulphate	1.23	5		.99		.94	1.4	4.44	9.15	106	1.138	1.085
8	"	Sodium Sulphate	2.86	10		2.39		2.15	2.2	4.48	8.84	97	1.138	1.122
11	"	Sodium Chloride	.67	5			.28	.25	3.0	4.39	9.11	108	1.138	1.102
12	"	" "	1.39	10			.62	.56	5.8	4.42	8.71	97	1.138	1.099
13	"	" "	2.83	20			1.73	1.60	8.6	4.39	8.97	104	1.138	1.092
14	"	" "	4.34	30			2.55	2.99	8.0	4.57	8.57	88	1.138	1.115
15	"	" "	5.86	40			3.32	3.63	14.7	4.68	8.51	82	1.138	1.134
16	"	" "	7.58	50			5.00	5.16	14.6	4.48	8.13	81	1.138	1.179
17	Wood	Pure water	0	0						14.63	15.98	10.9	.358	.765
18	"	Sodium Chloride	1.39	10			.97	.88	3.6	14.54	15.74	10.7	.358	.733

twenty kernels than with such seeds as rape and Scirpus where the three grams used numbered over a thousand seeds. In the more concentrated solutions of sodium chloride running up to fifty atmospheres the irregularities after forty-eight hours became noticeable but find a partial explanation in the amount of salt absorbed. The real osmotic pressure tending to prevent absorption of water was not in any case fifteen atmospheres at the end of the experiment. The sodium carbonate attacked the corn at once and disintegrated the kernels so the tests in these solutions were soon stopped. To see whether physiological forces were concerned in the imbibition of water before germination a parallel test was made with dry pine wood cut into cylinders about 50 mm. long by 5 mm. diameter. Water is absorbed in much the same way by wood as by seeds and the presence of salt in solution diminishes and retards the imbibition.

It will be noticed that some of the salts are absorbed to a much greater extent than others under originally the same "head" of osmotic pressure and this produces a difference in the amount of water imbibed. It was thought that the forcing of the salt into the seed by osmotic pressure must be similar to forcing it through water by the action of the same force and if so the salts would be absorbed in the order of their diffusibility. Dividing the amount of the salts absorbed per hundred weight of dry seed by the equivalent weights gives the relative number of molecules forced into the corn in six and a half days, and these numbers may be compared with the number of molecules forced through water in a given time by osmotic pressure as discovered by Long.*

	No. of Molecules Diffused Through Water.	No. of Molecules Absorbed By Corn	
		5 Atmos.	10 Atmos.
½ Sodium sulphate	678	132	303
Sodium chloride	600	43	95
½ Magnesium sulphate	348	31	76

It appears from this that salts under the same osmotic pressure are absorbed by seeds in the order of their diffusibility. The ratio is not exactly the same but that could not be expected under the crude conditions of the experiment in which the motive force was constantly changing.

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*Ostwald: Lehrbuch der allgemeinen Chemie, I, 691.

In this as in the preceding experiments the specific gravity was taken from a single sample and the "volumes before soaking" calculated from this. Doubtless it would have been more accurate to have determined the volume of each sample.

Plotting the curves of water absorbed in all the experiments shows that the curve is more nearly a straight line the stronger the solution. That is, the seeds in pure water absorb rapidly at first and soon cease while those in salt solutions absorb water more slowly and regularly, continuing to swell for a long time until they acquire nearly the same amount as in pure water. This is in accordance with the theory that the osmotic pressure tends to prevent imbibition at first, and that, as this is lessened by the accumulation of salt inside the seed, the imbibition may continue. Field work shows, too, that alkali retards rather than prevents germination and growth with many crops.

EFFECT OF ALKALI ON THE GERMINATION OF SEEDS.

In 1896 a series of experiments on the effect of alkali on the germination of seeds was carried on, the results of which were published in detail in Bulletin No. 29. The alkali used was that found on the Experiment Farm where it amounts to 2.25 percent on "the alkali plats," or, assuming 25 percent water in the soil, it is equivalent to a nine percent solution, which was used in these experiments. The other solution was made up on the basis of one percent of the soil or a four percent solution. The composition of the alkali is:

Sodium chloride	14.39 percent
Sodium sulphate	50.16 percent

Calcium sulphate ....15.41 percent
Magnesium sulphate ....20.03 percent

The osmotic pressure of this solution could not be exactly calculated, as the pressure of a salt in a mixture is not the same as when alone and the conductivity of calcium sulphate is not known, but the osmotic pressures are not far from 16 and 33 atmospheres respectively. Table VIII gives a summary of the results and shows that salts in solution retard and prevent germination in all cases but that there is a wide difference in the extent of the deleterious effects of alkali on different crops.

TABLE VIII.—*The Effect of Alkali on the Germination of Seeds.*

Crop.	Per cent alkali in solution.	Osmotic pressure Atmospheres.	Per cent. germinated in			Number of days to germinate.	
			10 days.	15 days.	25 days.	50 per cent	90 per cent
Turnips	0	0	84	85	85	5	. .
"	4	16	0	4	43	30	. .
"	9	33	0	0	0	. .	. .
Barley	0	0	98	98	98	3	4
"	4	16	86	97	97	9	12
"	9	33	3	25	42	. .	. .
Rye	0	0	96	96	96	2	4
"	4	16	80	91	94	3	11
"	9	33	75	84	91	9	21
Oats	0	0	72	94	94	8	12
"	4	16	1	14	26	. .	. .
"	9	33	. .	. .	. .	. .	. .
Wheat	0	0	85	88	92	5	16
"	4	16	34	56	68	11	. .
"	9	33	2	6	33	. .	. .
Alfalfa	0	0	100	100	100	5	6
"	4	16	23	80	99	11	17
"	9	33	1	1	3	. .	. .

THE GERMINATION OF WHEAT AND RYE IN SALT SOLUTIONS.

To determine what kinds of alkali and in what amounts were most deleterious a germination experiment was carried out by Mr. Fairfield under the direction of Prof. Buffum, the details of which are given in another part of this report. To show in how far osmotic pressure was a factor in retarding germination, Table IX has been drawn up, giving the number of seeds of wheat and rye germinated out of fifty in

TABLE IX.—*Effect of Salt Solutions on the Germination of Wheat and Rye.*

Solution of	Strength, per cent.	Osmotic pressure.	Wheat.		Rye.	
			No. germinated in		No. germinated in	
			2 days	3 days	2 days	3 days
Pure water	0	0	15	24	46	47
Sugar	.1	.1	19	28	46	48
Magnesium Sulphate	.1	.3	12	25	40	46
Sodium Sulphate	.1	.4	12	19	47	49
Sodium Carbonate	.1	.5	24	37	46	46
Sodium Chloride	.1	.8	12	19	46	48
Sugar	.4	.3	17	29	46	47
Magnesium Sulphate	.4	1.2	11	30	45	48
Sodium Sulphate	.4	1.6	13	33	47	48
Sodium Carbonate	.4	1.8	3	21	38	41
Sodium Chloride	.4	3.0	7	25	41	48
Sugar	.7	.5	15	30	50	50
Magnesium Sulphate	.7	2.0	15	31	47	50
Sodium Sulphate	.7	2.8	6	23	46	48
Sodium Carbonate	.7	3.1	3	21	38	40
Sodium Chloride	.7	5.2	5	20	40	42
Sugar	1.0	7	12	31	47	48
Magnesium Sulphate	1.0	2.8	11	29	45	47
Sodium Sulphate	1.0	3.9	3	23	40	43
Sodium Carbonate	1.0	4.3	0	6	26	26
Sodium Chloride	1.0	7.4	0	9	32	43
Sugar	2.0	1.4	15	20	40	43
Magnesium Sulphate	2.0	2.8	7	17	34	40
Sodium Sulphate	2.0	7.5	2	12	32	35
Sodium Carbonate	2.0	8.1	0	1	6	7
Sodium Chloride	2.0	14.2	0	5	17	27
Sugar	3.0	2.1	16	25	47	47
Magnesium Sulphate	3.0	7.7	4	20	42	46
Sodium Sulphate	3.0	11.1	0	9	14	22
Sodium Carbonate	3.0	11.6	0	0	2	7
Sodium Chloride	3.0	21.1	0	0	1	6
Sugar	4.0	2.8	16	30	42	44
Magnesium Sulphate	4.0	10.2	0	11	19	27
Sodium Sulphate	4.0	13.7	0	7	3	15
Sodium Carbonate	4.0	15.0	0	0	1	2
Sodium Chloride	4.0	27.7	0	0	0	0
Sugar	5.0	3.5	14	24	46	48
Magnesium Sulphate	5.0	12.6	0	3	15	26
Sodium Sulphate	5.0	17.0	0	0	0	8
Sodium Carbonate	5.0	18.4	0	0	0	0
Sodium Chloride	5.0	34.3	0	0	0	0
Sugar	7.0	4.9	7	22	43	47
Magnesium Sulphate	7.0	17.2	0	1	8	17
Sodium Sulphate	7.0	23.3	0	0	0	0
Sodium Carbonate	7.0	20.1	0	0	0	0
Sodium Chloride	7.0	46.6	0	0	0	0

two and three days in comparison with the osmotic pressure tending to prevent the necessary preliminary absorption of water. The results are very irregular, partly on account of individual peculiarities of the seeds and partly because concentration of the solutions in contact with the seeds could not be as accurately maintained as in the other experiments. In most cases the number germinated in two or three days is in inverse order to the osmotic pressure. At the end of five or ten days, as may be seen from the complete tables, however, there is little difference noticeable, showing that in dilute solutions the alkali retards but does not prevent germination. Stronger solutions prevent the germination of many of the seeds altogether. Sodium carbonate in very dilute solutions seems to stimulate germination, in stronger solutions it destroys the seed. Rye is not so much affected by alkali as wheat. Five atmospheres osmotic pressure by whatever salt it may be produced interferes seriously with the germination of wheat during the first three days and ten atmospheres prevents it almost entirely. Ten and fifteen atmospheres pressure produce a corresponding effect on rye.

ANALYSES OF WYOMING ALKALI.

Several analyses of alkali from various parts of the state that have not previously been reported are given in Table X. The samples are in most cases simply the white deposit on the ground to the depth of an inch or two, so the

TABLE X.—*Analyses of Wyoming Alkali.*

No.	Place and Date.	Percentage of alkali in soil.	Percentage composition.			
			Sodium sulphate	Sodium Chloride	Mag. sulphate	Sodium carbonate.
1	Two miles west of Lander, June '97	17.01	51.61	1.96	46.43	. . .
2	Wind River Board School Garden, June '97	15.34	82.55	8.39	9.06	. . .
3	Bel'e Springs, 15 miles north of Rawlins, June '97	3.72	29.35	17.42	53.23	. . .
4	21 miles north-west of Rawlins, June '97	.08	57.20	28.40	14.40	. . .
6	Buffalo school grounds, '96	7.62	96.20	1.19	2.61	. . .
7	Bitter Creek bed, June '97	8.00	89.51	6.89	3.60	. . .
8	Point of Rocks, near Bitter Creek, June '97	.86	25.90	74.10	. . .	. . .
9	Orenda Buttes, September '97	7.20	50.41	4.08	. . .	45.51
10	Dry pond near Granger, June '97	63.90	75.98	3.57	20.45	. . .
75	Ione farm, 1891	1.82	13.58	56.18	30.24	. . .

percentage of alkali in the soil as given does not mean anything very definite.

In reporting these analyses, calcium sulphate has been excluded for the following reasons: First, it is never injurious and even a saturated solution of it is probably beneficial. Second, the amount of calcium sulphate reported as alkali depends merely on the method of extraction. In all parts of the state, except in the carbonate region, the soil contains a large amount of gypsum and if the soluble salts are extracted by percolation, one may continue to dissolve it indefinitely. If the other method is used, of shaking up, say one hundred grams of soil in two hundred cubic centimeters of and filtering a portion for analysis, the amount of calcium sulphate obtained is still dependent on the proportions of soil and water. There should be an official definition and method of extraction for alkali adopted by the Association of Official Agricultural Chemists. As it is now there are so many ways of reporting soluble salts, that comparison of published analyses is very difficult. In the analyses here given calcium sulphate has been determined, subtracted, and the result recalculated on the basis of true soluble salts.

DISCUSSION OF RESULTS.

The temptation to theorize from these incomplete results could not be entirely resisted, but speculation has been confined to the following paragraph: That water should be absorbed by a seed or plant from a solution offering a great opposing osmotic pressure is not surprising when we consider the enormous forces concerned in imbibition. The wetting of blocks of wood is used for splitting granite rocks and raising buildings. Internal osmotic pressures of living plant cells has been measured to twenty atmospheres.*

That the forces concerned in the absorption of water and salts by the seed and probably by the plant roots are physical or chemical rather than physiological* is evident, but it is not yet known exactly what they are. The fact that the salts absorbed from soil solutions are not always the same as those reported by chemical analysis to be in the solution, was a source of great perplexity to the older botanists, who were obliged to ascribe very remarkable selective powers to the root hairs. According to the modern theory of solutions this offers no difficulty since it is known that salts do not exist as such in solutions but in their ionic form. The experiments here given indicate some relation between the diffusibility of salts and their absorption by seeds. If further experiment shows this to be general and applicable also to roots it would apparently give foundation for a theory of the selective absorption of salts by plants. Potassium for example has a migration velocity of 59.7 compared to 41.1 for sodium, which may account for potassium being taken up by the plant in preference to sodium, regardless of their original proportions in the soil. It has long been known but never explained, that the presence of non-nutritive salts in the soil influences to the marked degree the absorption of plant food. Now it is found that the diffusibility of a salt is different when mixed with other salts from what it is when alone. When two salts are in solution together the more rapid is accelerated and the slower is retarded, both absolutely and relatively.§ For example: The addition of gypsum to the soil would therefore increase the amount of potassium diffused into a plant, a result which is in accordance with fertilizer practice and suggests the possibility that a rational system in the use of fertilizers may eventually replace the present empiricism. It would be easy to calculate exactly what salts added to a soil solution would produce the greatest acceleration to the nutritious elements and retard the deleterious. Selction absorption of salts is of course not a property of living matter alone. Charcoal, soil, sand or filter paper will absorb certain salts from a solution and leave others or even take out the basic party of a salt, leaving the solution acid.* Ionic migration velocities and absorption will certainly go far toward explaining the phenomena of plant nutrition. If the positive ions diffuse into the plant more rapidly than the negative ions, there would be a difference of electrical potential, and the soil solution around the roots would become acid. Both these phenomena have been observed, but it has been supposed that the root hair "excreted" the acid which is able to decompose granite fragments. It would seem a possible hypothesis that this acid, which is equivalent to hydrochloric acid of 1.115 specific gravity, might be produced by the acid radicles left behind in the soil when the positive ions entered the plant.

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*Noll: Lehrbuch der Botanik fur Hochschulen, p. 139.

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*The word physiological is used here in its customary sense to include phenomena of life not otherwise classified. It is a euphemism for ignorance like the word chance in physics and fate in metaphysics.

§Ostwald: Lehrbuch der allg. Chemie, I, 695.

A difficulty in the way of the study of the effects of salts in solution on plants and seeds that will probably prevent any exact numerical relations being established between the concentration, the solution and the imbibition of water, is that owing to absorption the concentration of the solution on the surface of seeds, roots and soil grains is not the same as that of the free solution. No method for determining the correction to be applied for this is at present known.

So much attention has been given to injurious effects of alkali that it has generally been overlooked that the abundance of soluble salts in the soil is of benefit in several ways to plants that can stand it. There is always more water in alkali soil's than in other, partly because it lessens evaporation. The evaporation from a 16.16 percent solution of common salt calculated from the vapor pressure is eight percent less than from pure water.* Whether the same ratio holds for the evaporation from soil wet with pure water and with salt solutions is not known. Plants growing in alkali land have a large amount of salts in their sap. This helps the plant to acquire water from the soil by increasing the internal osmotic pressure and also to preserve its water by lessening transpiration. It would seem better policy to try to grow agricultural plants that can endure and use the alkali as some weeds can, rather than to attempt to eliminate it from the soil. Experiments have proved that it is possible to accustom certain of the lower plants and animals to different osmotic pressure of the surrounding medium.§ It is possible that something could be done with useful plants in the way of acclimatizing them to the arid region either by selection or development.

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*Ostwald I, 1094.

FUTURE WORK.

A number of experiments have been carried out on the growth of plants in salt solutions on the same lines as those on imbibition and germination but will be continued another year before publication. More work will also be done in the absorption of water and salts by seeds and plants to test the theories here suggested, particularly in regard to ionic velocities and the effect of solutions of mixed salts. Analyses of plants immune to the bad effects of alkali are being made in connection with the study of the botanist of the station on their structure. When the cause of immunity is more thoroughly understood, experiments on the acclimination of useful plants to the conditions of the arid region will be conducted in a more extensive and systematic way than is being done here at present. Experiments on evaporation from solutions, from soils containing alkali and from plants in such soils are now under way. There is much need of light on the subject of the effect of soil salts on transpiration.*

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*Nernst: Theoretical Chemistry, p. 226.

§The best resume of the work done on the relation of osmotic pressure to plant life is found in Davenport; Experimental Morphology, Vols. I and II.

The above statement of the work we are undertaking is published for the purpose of putting us in communication with other stations working on the same problems. The possible lines of investigation are so much more numerous than the workers that it is a great pity the labor should be wasted in duplication because of lack of coöperation.

SUMMARY.

Experiments on the imbibition of water by a large number of different kinds of seeds show that in all cases the presence of salts in solution hinders the absorption of water. Isosmotic solutions produce nearly the same effect, showing that the osmotic pressure is more important than the kind of salt. Retardation of imbibition does not increase proportionally with the osomotic pressure or with the concentration of the solution, but less rapidly. An osmotic pressure of five or ten atmospheres retards the imbibition of water to a considerable extent with all seeds and in dilute solutions a difference of one atmosphere makes a perceptible difference in most cases. Salts are absorbed from solution by seeds but not in the proportion in which they exist in the water. The accumulation of salt in the seed is gradual, so the osmotic pressure of the solution in the seed tends to approach that outside. That the imbibition of water is not due to the action of life is shown by the fact that similar results are obtained from living and dead seeds and dry wood. Dilute solutions of the common alkali salts do not poison the seed or prevent its germination when the conditions become more favorable. Different salts are absorbed from solutions in proportion to their diffusibility. The percent of water imbibed by seeds in distilled water before their germination is as follows: Corn 106, sunflower

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*Maxwell's results (American Chem. Journal, XX, 469) are in direct contradiction to the statements in the text books.

137, peas 120, buckwheat 65, rape 57, scirpus 33, wheat 62. The germination of seeds in various salt solutions gives results similar to those on the imbibition of water. Wyoming alkali consists principally of sodium sulphate, sodium chloride and magnesium sulphate in varying proportions, but in some parts of the state the magnesium sulphate is replaced by sodium carbonate.

METEOROLOGICAL REPORT

—FOR THE YEAR—

Beginning January 1, and Ending December 31, 1898.

BY C. B. RIDGAWAY.

Meteorological Report For 1898.

The work of the meteorological department has been a continuation of that of previous years. Observations upon atmospheric conditions and soil temperature at various depths have been taken twice daily, at 7 a. m. and 7 p. m.

The observations have been reported monthly to the United States Weather Bureau at Washington, and to the Wyoming Section at Cheyenne. Weekly climate and crop reports have also been sent to the Cheyenne office.

The latitude of the Station is 41° 18′ 37.09″ North, and the longitude 105° 34′ 53.75″ West from Greenwich. The altitude of the standard barometer is 7,191 feet.

The equipment of the Station for meteorological observations consists of the following: A quadruple register, with two automatic pens for registering the velocity and direction of the wind; a Draper's self-recording thermometer; a standard mercurial barometer; one Richard's self-registering aneroid barometer; a sling psychrometer; six soil thermometers at different depths in the ground; a maximum and a minimum self-registering thermometer; a hook-gauge and evaporation tank; a standard eight-inch rain gauge; a maximum and a minimum self-registering solar radiation thermometer.

Summary.

Highest temperature, 88, June 30 and July 26.
Lowest temperature, —23, January 26.
Mean temperature for the year, 38.3.
Greatest daily range of temperature, 57, June 29.

Lowest daily range, 3, February 22.

Mean daily range of temperature for the year, 26.4.

Mean relative humidity for the year, 57.6.

Lowest relative humidity, 13, July 26 and September 19.

Highest dew point, 58, July 10.

Lowest dew point, —21, December 9.

Mean dew point for the year, 23.8.

Greatest terrestrial radiation, 12, June 11.

Mean terrestrial radiation for the year, 3.9.

Highest barometer, 23.408.

Lowest barometer, 22.47.

Mean barometer for the year, 23.020.

Highest monthly precipitation, 1.88 in., in June.

Lowest monthly precipitation, traces in September.

Highest precipitation during any single storm, .55 in., August 4.

Total precipitation: 1891, 13.92 in.; 1892, 12.73 in.; 1893, 3.84 in.; 1894, 7.63 in.; 1895, 11.15 in.; 1896, 10.75 in.; 1897, 11.99 in.; 1898, 7.63 in.

Mean precipitation for eight years, 9.95 in.

Evaporation, 41.40 inches, from April 15 to October 15.

Greatest monthly evaporation, 10.33 inches in June.

Mean soil temperatures: 3 in., 42.3; 6 in., 44.3; 12 in., 44.0; 24 in., 44.8; 36 in., 45.3; 72 in., 44.5.

Prevailing direction of the wind, southwest.

Greatest velocity of wind, 60 miles per hour.

Total number of miles traveled by wind during the year (351 days), 99,571.*

Greatest number of miles traveled in one month, 11,118, in March.

Lowest number of miles traveled in one month, 4 854, in August.

Average number of miles for each month. 8,297.6.

Greatest number of miles in one day, 700, October 3.

Least number of miles in one day, 24, August 17.

Mean daily distance traveled, 283.7.

Mean hourly distance traveled, 11.8.

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*While the instrument tower was being moved farther back from the buildings, and at other times, the wind record was incomplete. If we multiply 283.7 miles, the daily average, by 365, the number of days in a year, it will give 103,505 miles, which is very near the correct number of miles for the year.

TABLE I.*—*Temperature, 1898.*

	JANUARY.						FEBRUARY.						MARCH.					
Date.	7 a.m.	7 p.m.	Max.	Min.	Mean.	Daily Range.	7 a.m.	7 p.m	Max.	Min.	Mean	Daily Range.	7 a.m.	7 p.m.	Max.	Min.	Mean	Daily Range.
1	10	10	25	—12	7	37	9	21	29	3	16	26	25	25	37	23	30	14
2	28	35	38	4	21	34	8	21	31	7	19	24	23	25	38	16	27	12
3	31	23	**47**	23	35	24	24	31	41	17	29	24	22	35	49	15	32	34
4	12	20	32	8	20	24	17	19	28	17	22	11	30	34	43	23	33	20
5	21	33	41	10	25	31	25	43	48	17	33	31	31	29	40	25	32	15
6	20	30	43	20	32	23	33	39	43	27	35	16	26	33	50	16	33	34
7	30	28	37	22	30	15	23	32	44	20	32	24	36	42	**52**	21	36	32
8	25	24	38	21	29	17	25	28	44	22	33	22	33	15	40	17	33	32
9	15	28	37	12	20	25	24	20	29	19	25	10	28	28	42	15	29	27
10	21	25	43	15	29	28	5	24	32	4	18	28	20	22	35	17	26	18
11	7	10	27	4	15	23	8	20	34	5	20	29	8	21	28	2	15	26
12	6	11	27	—4	11	31	24	30	40	14	27	26	18	28	34	16	25	18
13	10	14	31	—3	14	34	13	32	38	8	23	30	31	37	48	23	35	25
14	8	6	18	4	11	14	34	35	36	**2**	19	**34**	17	17	23	15	19	**7**
15	9	18	27	—1	13	28	34	37	38	32	35	6	19	20	32	12	22	20
16	11	17	28	10	19	18	20	35	**49**	26	38	23	15	25	39	11	25	28
17	11	14	19	8	14	11	9	16	25	7	16	18	26	33	50	14	32	36
18	—1	10	21	—3	9	24	10	19	28	7	17	21	33	21	40	15	33	25
19	15	18	27	6	16	21	20	15	27	12	20	15	18	23	30	11	20	19
20	4	11	18	—1	8	19	22	32	32	8	20	24	24	26	38	18	28	20
21	1	3	15	—4	5	19	20	35	35	16	26	19	26	4	40	12	21	38
22	13	20	25	—4	11	29	22	18	20	17	19	**3**	—6	—7	4	—6	—1	10
23	12	17	18	5	11	13	9	30	30	7	18	23	7	22	30	**—10**	10	**40**
24	5	2	7	0	3	**7**	16	38	37	13	25	24	27	36	47	20	34	27
25	—4	—4	9	—10	0	19	38	35	40	32	26	8	37	41	50	25	37	25
26	—3	12	15	**—23**	—4	**38**	24	32	46	21	36	25	35	19	46	20	33	26
27	18	28	34	10	22	24	26	29	45	17	31	28	8	20	46	14	30	32
28	5	19	25	14	20	11	33	37	48	22	35	26	19	23	46	7	26	30
29	26	25	33	25	29	8							13	22	37	7	22	30
30	20	21	31	20	25	11							19	25	33	7	30	26
31	19	20	34	20	27	14							25	26	35	12	24	23
Sum.	385	548	870	196	527	674	584	803	1017	419	713	508	693	773	1211	433	831	778
Mean.	12.4	17.7	28.0	6.3	17.0	21.7	20.8	28.7	36.3	14.9	25.5	21.4	22.3	24.0	39.0	13.9	26.8	25.1

* In all the tables figures printed in bold faced type give the highest or lowest readings for each month.

TABLE I (Continued).—*Temperature, 1898.*

	APRIL.						MAY.						JUNE.					
Date.	7 a.m.	7 p.m.	Max.	Min.	Mean.	Daily Range.	7 a.m.	7 p.m.	Max.	Min.	Mean.	Daily Range.	7 a.m.	7 p.m.	Max.	Min.	Mean.	Daily Range.
1	18	28	42	10	26	32	26	26	29	24	27	5	58	64	74	38	56	36
2	40	46	61	18	40	43	27	30	38	21	29	17	61	65	76	44	60	32
3	36	22	60	22	41	38	28	28	35	26	31	9	48	47	54	36	45	18
4	25	22	40	15	27	25	25	30	37	24	30	13	27	42	48	33	41	15
5	18	20	42	2	22	40	30	31	38	23	31	15	42	49	58	29	44	29
6	21	36	50	10	30	40	33	39	52	20	36	32	45	51	61	34	47	27
7	31	34	43	25	34	18	44	43	59	29	44	30	47	50	63	36	50	27
8	33	40	48	26	37	22	36	39	54	31	42	23	50	51	60	41	50	19
9	38	41	55	26	36	31	38	49	59	31	45	28	52	51	63	40	52	23
10	43	49	62	24	43	38	47	56	65	30	47	35	50	47	70	35	52	35
11	41	36	51	30	40	21	54	45	66	41	54	25	52	49	64	42	53	22
12	32	37	48	28	38	20	46	47	59	34	46	25	53	54	65	41	53	24
13	38	49	61	26	44	35	50	47	62	38	50	24	52	58	60	48	54	12
14	47	56	67	35	51	32	45	45	57	31	44	26	55	57	69	46	57	23
15	33	54	72	27	50	45	48	47	59	34	46	25	57	68	73	44	59	29
16	45	48	69	42	55	27	46	41	55	40	48	15	60	67	79	43	61	36
17	38	41	44	30	37	14	40	38	49	31	40	18	64	68	82	42	67	40
18	35	45	56	23	40	33	44	44	55	42	49	13	61	68	79	40	64	30
19	36	42	56	28	42	28	45	40	49	33	44	23	65	61	75	43	59	32
20	48	49	62	33	48	29	38	49	49	33	41	16	64	63	84	44	64	40
21	48	39	48	33	40	15	40	50	58	29	44	29	60	72	83	39	61	44
22	43	44	50	29	39	21	53	67	71	28	48	43	66	64	85	45	65	40
23	41	39	51	31	41	20	57	65	73	32	53	41	62	62	76	46	61	30
24	38	46	56	23	40	33	48	45	65	36	50	29	62	69	76	44	60	32
25	43	56	66	25	46	41	47	52	57	38	47	19	64	69	78	48	63	30
26	56	63	74	30	57	35	46	47	51	43	47	18	57	68	76	48	42	28
27	39	36	47	36	40	11	49	51	65	38	52	27	59	73	81	38	50	43
28	40	51	60	24	42	36	48	48	58	40	49	18	68	73	87	38	63	40
29	46	35	57	34	45	23	47	57	62	37	50	25	60	66	86	29	57	57
30	34	32	43	30	37	13	58	52	68	35	51	33	72	75	88	44	66	44
31							45	54	62	40	51	22						
Sum.	1124	1236	1641	784	1208	859	1328	1404	1716	1012	1366	721	1693	1821	2173	1227	1685	946
Mean.	37.5	41.2	54.7	26.1	40.3	28.6	42.8	45.3	55.3	32.6	44.1	23.2	56.8	60.7	72.4	40.9	56.8	31.5

TABLE I (Continued).—*Temperature 1898.*

	JULY.						AUGUST.						SEPTEMBER.					
Date.	7 a.m.	7 p.m.	Max.	Min.	Mean.	Daily Range.	7 a.m.	7 p.m.	Max.	Min.	Mean.	Daily Range.	7 a.m.	7 p.m.	Max.	Min.	Mean.	Daily Range.
1	54	59	73	38	55	35	51	53	67	42	54	25	61	61	72	54	63	18
2	50	57	65	50	57	15	50	63	72	38	55	34	60	57	76	50	63	26
3	55	61	70	58	64	12	52	75	81	41	64	34	52	57	71	42	56	29
4	60	73	83	67	75	16	68	62	85	55	70	30	50	60	71	39	55	32
5	66	67	79	50	64	29	58	49	68	48	58	20	53	38	71	37	54	34
6	64	67	79	50	64	29	48	54	67	47	57	20	34	48	60	23	42	37
7	65	71	82	65	73	17	53	59	68	50	59	18	46	48	71	34	52	37
8	64	60	79	52	65	27	52	62	77	43	60	34	42	55	69	34	52	35
9	64	68	83	59	71	24	59	64	77	42	59	35	36	34	42	32	37	10
10	65	70	80	63	72	17	55	58	77	44	60	33	43	33	43	30	37	13
11	62	66	80	63	72	17	55	64	78	44	61	34	32	38	50	19	35	31
12	64	65	77	53	65	24	55	69	83	43	63	40	32	42	65	20	42	45
13	66	70	81	55	68	26	60	69	81	44	62	37	39	49	65	25	45	40
14	62	69	80	50	65	30	61	67	80	51	65	29	49	55	73	30	52	43
15	60	64	81	49	65	32	63	69	82	45	63	37	49	63	73	35	54	38
16	56	70	80	48	64	32	58	50	75	45	60	30	43	47	60	40	50	20
17	67	68	78	53	65	25	58	63	79	50	64	29	47	60	76	36	56	40
18	68	71	79	47	63	32	55	74	85	41	63	44	51	60	75	38	56	37
19	60	67	74	51	62	23	57	68	85	55	70	30	44	65	72	34	53	38
20	57	65	75	47	61	28	64	70	82	55	67	29	57	61	71	34	52	37
21	63	71	80	47	64	33	62	64	84	53	68	37	53	55	76	46	61	30
22	62	74	84	48	66	36	58	67	78	54	66	24	49	60	75	37	56	38
23	65	62	81	49	65	32	59	62	74	51	62	23	54	55	71	49	60	22
24	62	67	74	49	62	25	52	67	81	41	61	40	45	58	77	38	58	39
25	62	73	84	52	73	32	55	62	83	42	62	41	46	55	78	34	56	44
26	50	76	83	50	69	38	54	70	85	42	63	43	42	60	79	34	56	45
27	63	72	83	46	65	37	61	55	84	48	66	36	54	54	76	41	58	35
28	68	72	85	46	65	39	60	65	80	48	64	32	45	57	70	36	53	34
29	65	62	77	46	62	31	61	70	86	50	68	36	38	45	55	34	44	21
30	58	52	76	46	60	30	69	65	85	55	70	30	49	60	72	28	50	44
31	59	58	68	44	59	24	60	57	78	55	66	23						
Sum.	1906	2067	2436	1588	2017	847	1782	1995	2447	1462	1950	987	1395	1590	2055	1063	1558	992
Mean.	61.5	66.7	78.6	51.2	65.1	27.3	57.5	64.3	78.9	47.2	62.9	31.8	46.5	53.0	68.5	35.4	51.9	33.1

TABLE I (Continued).—*Temperature 1898.*

	OCTOBER.						NOVEMBER.						DECEMBER.					
Date.	7 a.m.	7 p.m.	Max	Min.	Mean.	Daily Range.	7 a m.	7 p.m.	Max.	Min.	Mean.	Daily Range.	7 a.m.	7 p.m.	Max.	Min	Mean	Daily Range.
1	55	42	68	53	60	15	32	31	45	25	35	20	20	23	29	17	23	12
2	30	35	49	28	39	21	39	32	51	21	36	30	20	13	21	14	17.5	**7**
3	31	42	48	26	37	22	36	45	55	27	41	28	4	—1	17	—2	7 5	19
4	29	37	48	23	35	25	37	40	50	33	41	17	16	25	33	- 3	15	36
5	31	40	52	28	40	24	32	35	48	22	35	26	25	8	35	7	21	28
6	32	41	66	27	47	39	41	45	**61**	20	41	41	0	11	21	—7	7	28
7	38	45	61	32	46	29	46	20	39	20	30	19	15	12	19	8	13.5	11
8	33	47	70	23	46	47	14	0	22	—1	11	23	—4	—10	5	- 12	—3.5	17
9	43	41	53	38	48	20	1	8	13	**—12**	.5	30	—21	—10	1	**—22**	—10.5	23
10	38	44	56	34	45	22	19	30	35	6	20.5	29	—10	—6	12	—19	- 3.5	31
11	43	53	63	38	51	25	3	13	22	0	11	22	—8	7	25	—11	7	36
12	39	40	49	37	43	12	—4	13	21	—6	8	27	14	0	32	6	19	26
13	28	44	68	19	44	**49**	3	5	20	—1	9	21	9	21	37	—4	16.5	**41**
14	45	53	**69**	30	49	39	9	18	35	1	18	34	12	15	42	6	24	36
15	35	27	55	26	40	29	21	35	40	17	28	23	0	14	27	—4	11.5	31
16	24	25	31	11	21	20	18	19	31	16	24	15	14	22	39	5	22	34
17	17	29	40	13	27	27	24	33	34	17	25	17	8	14	42	3	22.5	39
18	34	31	41	25	33	16	35	36	46	32	39	14	2	19	39	0	19.5	39
19	24	19	27	16	22	**11**	34	38	57	35	46	22	14	27	39	0	19.5	39
20	19	23	30	**7**	19	23	36	2	45	2	23	**43**	24	27	30	15	22.5	15
21	23	36	47	13	30	34	-2	6	10	—4	3	14	12	7	18	1	9.5	17
22	35	46	60	30	45	30	15	15	25	—4	10	29	8	13	18	3	10.5	15
23	43	39	54	35	45	19	12	19	27	8	18	19	3	4	14	—1	6.5	15
24	27	21	41	21	31	20	10	16	23	8	16	15	9	9	21	0	10.5	21
25	16	30	44	12	28	32	12	20	34	5	19	29	21	21	31	9	20	22
26	34	45	58	27	42	31	10	25	47	13	30	34	26	30	36	21	28.5	15
27	33	38	50	30	40	20	22	28	37	16	28	21	28	31	42	31	36.5	11
28	36	28	44	26	45	18	28	20	30	15	23	14	29	35	**45**	28	36.5	17
29	16	29	47	13	30	34	20	28	28	15	22	13	18	4	18	4	11	14
30	35	49	62	21	42	41	17	21	27	17	22	**10**	10	2	13	—14	—.5	27
31	44	49	60	41	50	19							—5	4	11	—7	2	18
Sum.	1010	1168	1611	813	1220	803	620	696	1063	366	715	609	315	395	802	72	442	740
Mean.	32.6	37.7	51.9	26.2	39.3	25.9	20.6	23.2	35.4	12.2	23.8	23.3	10.2	12.7	25.9	2.32	14.3	23.0

TABLE II.—*Terrestrial Radiation.*

Date.	JANUARY			FEBRUARY			MARCH			APRIL			MAY			JUNE		
	Min.	Ter. Ther.	Rad.	Min.	Ter. Ther.	Rad.	Min.	Ter. Ther.	Rad.	Min.	Ter. Ther.	Rad	Min	Ter. Ther.	Rad.	Min.	Ter. Ther.	Rad.
1	—12	—16	4	3	0	3	24	21	3	10	16		24	30	4	38	34	4
2	4	0	4	10	7	3	16	11	5	17	15	2	22	20	2	44	43	1
3	24	18	6	18	14	4	15	12	3	30	29	1	26	28	0	38	36	2
4	8	4	4	21	19	2	23	21	2	9	0	9	25	25		33	32	1
5	11	5	6	19	14	5	25	22	3	12	3	9	23	22	1	29	25	4
6	24	16	8	27	27	0	16	12	4	10	8	2	20	16	4	34	37	
7	22	16	6	23	18	5	18	15	3	28	28	0	30	25	5	36	37	
8	21	19	2	25	18	7	32	28	4	29	23	6	31	28	3	41	36	5
9	13	9	4	22	20	2	15	11	4	27	20	7	31	29	2	40	37	3
10	15	12	3	4	0	4	18	18	0	24	16	8	30	26	4	35	31	4
11	5	2	3	5	—1	6	6	4	2	31	26	5	41	37	4	43	31	12
12	—4	—6	2	18	14	4	16	14	2	29	27	2	35	33	2	42	37	5
13	—3	—4	1	9	3	6	24	22	2	27	22	5	38	35	3	43	39	4
14	6	4	2	18	29		16	18		35	31	4	32	29	3	47	44	3
15	0	—3	3	32	30	2	13	12	1	27	21	6	35	34	1	44	40	4
16	10	8	2	27	24	3	12	6	6	34	27	7	42	41	1	43	38	5
17	8	7	1	7	3	4	16	19		30	24	6	32	28	4	43	40	3
18	—2	—5	3	8	5	3	17	12	5	24	21	3	38	37	1	49	45	4
19	7	5	2	15	11	4	13	8	5	29	24	5	32	28	4	53	47	6
20	0	—1	1	8	5	3	19	17	2	33	31	2	34	32	2	45	42	3
21	—4	—9	5	17	10	7	18	14	4	37	30	7	31	24	7	39	36	3
22	—4	—5	1	21	16	5	—8	—7	1	31	28	3	29	26	3	45	42	3
23	5	1	4	7	4	3	—10	—11	1	31	27	4	28	22	6	46	46	0
24	4	0	4	13	9	4	20	14	6	23	20	3	36	33	3	46	44	2
25	—10	—11	1	32	28	4	25	16	9	25	21	4	38	35	3	50	48	2
26	—23	—27	4	21	14	7	26	21	5	39	36	3	43	42	1	41	38	3
27	10	8	2	17	13	4	14	18		37	35	2	39	36	3	40	38	2
28	4	—2	2	22	16	6	7	6	1	24	18	6	41	41	0	41	38	3
29	19	12	7				8	2	6	39	35	4	37	33	4	36	29	7
30	20	15	5				8	5	3	39	32		36	35	1	54	44	10
31	20	14	6				12	10	2				41	45				
Sum.	198	86	108	469	370	110	474	391	94	811	694	125	1020	943	81	1258	1154	108
Mean.	6.4	2.8	3.5	16.7	13.3	3.9	15.3	12.6	3.0	26.2	22.4	4.0	32.9	30.4	2.8	41.9	38.5	3.9

TABLE II (Concluded).—*Terrestrial Radiation.*

Date.	JULY			AUGUST			SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER		
	Min.	Ter. Ther.	Rad.	Min.	Ter. Ther.	Rad.	Min.	Ter. Ther.	Rad.	Min.	Ter. Ther.	Rad.	Min.	Ter Ther.	Rad.	Min.	Ter. Ther.	Rad.
1				42	40	2	54	50	4	53	51	2	25	21	4	17	11	6
2				38	44		51	45	6	28	20	8	21	13	8	20	17	3
3				47	49		42	39	3	26	20	6	28	22	6	6	0	6
4				55	48	7	39	30	9	23	19	4	33	22	11	—3	—5	2
5				52	43	9	37	30	7	28	19	9	22	17	5	26	20	6
6				47	45	2	23	19	4	22	15	7	20	25		—6	—13	7
7				46	42	4	34	28	6	32	29	3	37	30	7	9	6	3
8				44	43	1	26	21	5	23	18	5	13	13		—8	—13	5
9				47	42	5	32	32		39	29	10	—12	—15	3	—22	—20	7
10				44	41	3	30	29	1	35	20	6	6	3	3	—19	—25	6
11				44	42	2	20	14	6	37	31	6	0	—5	5	—11	—16	5
12	53	49	4	43	41	2	20	17	3	38	31	7	—5	—10	5	6	0	6
13	55	52	3	44	42	2	25	20	5	19	16	3	0	—4	4	4	4	
14	50	46	4	51	48	3	31	27	4	30	27	3	1	—10	9	12	3	9
15	49	44	5	45	42	3	35	32	3	35	35		17	8	9	—4	—8	4
16	48	45	3	45	44	1	40	32	8	11	12		16	12	4	5	—3	8
17	54	49	5	50	48	2	36	32	4	15	13	2	11	8	3	3	—2	5
18	47	42	5	41	37	4	37	31	6	25	21	4	32	28	4	0	—4	4
19	52	46	6	55	53	2	34	28	6	17	13	4	34	30	4	1	—3	2
20	50	47	3	53	51	2	34	33	1	7	13		35	31	4	15	10	5
21	47	40	7	53	50	3	46	41	5	13	7	6	—4	—5	1	11	10	1
22	48	44	4	54	52	2	37	32	5	30	25	4	—4	—6	2	3	—2	5
23	49	44	5	51	45	6	49	45	4	35	41	4	8	6	2	0	—4	4
24	48	44	4	41	38	3	38	31	7	28	28		8	1	7	0	—2	2
25				42	41	1	34	27	7	12	19	2	5	1	4	9	5	4
26				41	39	2	34	32	2	27	23	4	13	7	6	21	18	3
27	41	36	5	48	45	3	41	37	4	31	25	6	18	14	4	27	22	5
28	47	44	3	48	51		36	29	7	33	27	6	26	21	3	28	25	3
29				49	45	4	34	34		13	9	4	15	12	3	5	18	
30				55	50	5	28	20	8	21	12	9	18	12	6	—12	—19	7
31				55	51	4				42	33	9				—7	—12	5
Sum.	738	672	70	1470	1392	89	1057	917	140	828	702	143	437	304	136	130	9	138
Mean.	49.2	44.8	3.9	47.4	44.9	3.2	35.2	35.7	5.0	26.7	22.6	5.3	14.6	10.1	4.9	4.2	0.3	4.5

TABLE III.—*Per Cent. of Saturation of the Air and Temperature of the Dew Point.*

Date.	JANUARY						FEBRUARY						MARCH					
	RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT		
	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a.m.	7 p.m.	Mean.	7 a m.	7 p.m.	Mean.	7 a m.	7p. m.	Mean.
1	68	65	66.5	**—18**	1	—8.5	86	**100**	93.	6	21	13.5	90	59	74.5	23	14	18.5
2	49	**41**	45.	10	14	12.	86	62	74.	5	11	8.	89	78	83.5	21	20	20.5
3	38	66	52.	11	14	12.5	55	63	59.	12	21	16.5	76	40	58.	16	14	15.
4	88	92	90.	9	18	13.5	57	48	52.5	6	4	5.	89	53	71.	27	20	23.5
5	78	65	71.5	15	23	19.	45	32	38.5	9	16	12.5	84	75	79.5	27	23	25.
6	77	73	75.	15	23	19.	51	32	41.5	18	13	15.5	60	49	54.5	15	17	16.
7	55	71	63.	17	20	18.5	77	57	67.	17	20	18.5	20	34	27.	1	18	9.5
8	68	80	74.	17	19	18.	77	69	73.	20	20	20.	51	71	61.	18	8	13.
9	75	60	67.5	8	17	12.5	**100**	77	88.5	24	15	19.5	43	**100**	71.5	10	**28**	19.
10	57	81	69.	10	20	15.	84	55	69.5	1	12	6.5	92	**100**	96.	18	22	20.
11	56	65	60.5	—3	1	—1.	62	77	69.5	—1	15	7.	86	75	80.5	5	15	10.
12	80	62	71.	1	2	1.5	56	73	64.5	12	23	17.5	87	60	73.5	15	17	16.
13	46	52	49.	—5	1	—2.	65	50	57.5	5	17	11.	63	62	62.5	21	26	23.5
14	86	80	83.	5	1	3.	72	76	74.	26	**29**	27.5	**100**	70	85.	17	10	13.5
15	64	71	67.5	0	11	5.5	58	40	49.	22	17	19.5	48	76	62.	4	14	9.
16	87	57	72.	7	6	6.5	51	52	51.5	15	21	18.	71	59	65.	8	14	11.
17	75	70	72.5	2	7	4.5	64	32	48.	0	**—7**	—3.5	60	47	53.5	15	19	17.
18	66	83	74.5	10	6	8.	83	36	59.5	6	—1	2.5	42	68	55.	14	11	12.5
19	54	71	62.5	3	11	7.	92	86	89.	18	12	15.	62	34	48.	8	1	4.5
20	83	83	83.	0	7	3.5	78	50	64.	16	17	16.5	57	48	52.5	12	11	11.5
21	75	83	79.	—4	—1	—2.5	77	41	59.	15	14	14.5	60	83	71.5	15	0	7.5
22	65	61	63	5	10	7.5	93	71	82.	20	11	15.5	**100**	63	81.5	—6	**—15**	—10.5
23	68	**100**	84.	4	17	10.5	64	**30**	47.	0	4	2.	61	50	55.5	—3	9	3.
24	84	**100**	92.	1	2	1.5	76	38	57.	10	17	13.5	67	38	52.5	19	15	17.
25	76	76	76.	—10	—10	—10.	**30**	48	39.	11	21	16.	**20**	24	22.	3	10	6.5
26	74	52	63.	—9	—1	—5.	80	56	68.	19	20	19.5	24	72	48.	4	12	8.
27	46	43	44.5	2	10	6.	78	61	69.5	21	19	20.	81	40	60.5	5	1	3.
28	84	75	79.5	1	13	7.	42	62	52.	14	26	20.	48	66	57.	4	14	9.
29	91	50	75.	**24**	14	19.							84	**100**	92.	10	22	16.
30	73	61	67.	14	11	12.5							75	68	71.5	13	17	15.
31	60	77	68.5	9	15	12.							79	90	84.5	20	23	21.5
Sum.	2146	2175	2160.5	151	302	228.5	1939	1574	1756.5	347	428	387.5	2069	1952	2010.5	379	430	404.5
Means	69.2	70.2	69.7	4.9	9.7	7.3	69.1	56.2	62.7	12.4	15.3	13.8	66.5	63.0	64.8	12.2	13.9	13.0

TABLE III.—*Per Cent. of Saturation of the Air and Temperature of the Dew Point.*

Date.	APRIL						MAY						JUNE					
	RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT		
	7 a. m.	7 p. m.	Mean	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.
1	87	60	73.5	15	17	16.	94	90	92.	24	24	24.	32	30	31.	31	34	32.5
2	34	36	35.	15	22	18.5	88	84	86.	25	26	25.5	30	18	24.	32	25	28.5
3	53	100	76.5	22	22	22.	68	70	69.	20	20	20.	67	93	80.	38	45	41.5
4	44	93	68.5	9	20	14.5	100	100	100.	25	30	27.5	100	70	85.	37	34	35.5
5	87	74	80.5	15	14	14.5	84	68	76.	26	23	24.5	85	55	70.	39	35	37.
6	93	47	70.	19	19	19.	75	68	71.5	26	29	27.5	79	75	77.	40	44	42.
7	100	86	93.	31	30	30.5	63	81	72.	32	37	34.5	66	68	67.	37	41	39.
8	85	45	65.	29	22	25.5	100	88	94.	36	35	35.5	51	69	60.	34	42	38.
9	54	50	52.	24	24	24.	87	37	62.	34	25	29.5	53	69	61.	37	42	39.5
10	42	40	41.	23	26	24.5	35	25	30.	31	22	26.5	81	100	90.5	45	47	46.
11	57	100	78.5	28	36	32.	40	82	61.	30	40	35.	81	80	80.5	47	44	45.5
12	100	48	74.	32	21	26.5	85	83	84.	42	42	42.	70	70	70.	44	45	44.5
13	67	34	50.5	28	23	25.5	27	76	51.5	18	40	29.	81	52	66.5	47	42	44.5
14	38	42	40.	23	33	28.	82	82	82.	40	40	40.	71	47	59.	47	39	43.
15	68	27	47.5	24	21	22.5	76	89	82.5	41	44	42.5	52	37	44.5	41	43	42.
16	51	48	49.5	28	29	28.5	75	96	85.5	38	40	39.	41	46	43.5	38	47	42.5
17	79	88	83.5	32	37	34.5	68	100	84.	30	38	34.	40	37	38.5	41	43	42.
18	91	31	61.	32	17	24.5	68	74	71.	34	36	35.	54	44	49.	46	47	46.5
19	86	58	72.	32	29	30.5	75	100	87.5	37	40	38.5	53	54	53.5	49	46	47.5
20	48	49	48.5	29	31	30.	50	57	53.5	22	35	28.5	36	51	43.5	39	46	42.5
21	66	100	83.	37	39	38.	53	46	49.5	25	30	27.5	41	30	35.5	38	41	39.5
22	68	56	62.	33	29	31.	47	32	39.5	33	35	34.	49	57	53.	48	50	49.
23	54	50	52.	26	23	24.5	22	29	25.5	20	33	26.5	51	47	49.	45	43	44.
24	69	36	52.5	29	22	25.5	95	100	97.5	46	45	45.5	47	28	37.5	43	37	40.
25	63	19	41.	31	18	24.5	83	66	74.5	42	41	41.5	26	22	24.	32	32	32.
26	29	16	22.5	25	17	21.	96	83	89.5	45	42	43.5	38	18	28.	34	27	30.5
27	57	38	47.5	26	15	20.5	83	77	80.	44	44	44.	28	22	25.	29	35	32.
28	34	18	26.	15	11	13.	58	48	53.	34	29	31.5	33	18	25.5	40	30	35.
29	72	100	86.	37	35	36.	47	29	38.	28	26	27.	32	37	34.5	33	41	37.
30	100	100	100.	34	32	33.	48	54	51.	38	36	37.	34	35	34.5	44	47	45.5
31							51	40	45.5	28	30	29.						
Sum.	1976	1689	1832.5	783	734	758.5	1129	1154	1141.5	994	1057	1025.5	1602	1479	1540.5	1195	1214	1204.5
Mean.	65.9	56.3	61.1	26.1	24.3	25.2	36.4	37.2	36.8	32.1	34.1	33.1	53.4	49.3	51.4	39.7	40.5	40.1

TABLE III.—*Per Cent. of Saturation of the Air and Temperature of the Dew Point.*

Date.	JULY						AUGUST						SEPTEMBER					
	RELATIVE HUMIDITY			DEW POINT.			RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT.		
	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean	7 a. m	7 p. m.	Mean.	7 a. m	7 p. m.	Mean.	7 a. m	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.
1	76	49	62.5	47	42	44.5	63	76	69.5	40	46	43.	68	59	63.5	**51**	**48**	49.5
2	68	34	51.	41	32	36.5	**87**	37	62.	46	38	42.	58	47	52.5	47	39	43.
3	55	59	57.	41	48	44.5	44	**23**	33.5	41	34	37.5	43	23	33.	32	23	27.5
4	49	28	38.5	42	40	41.	**23**	66	44.5	35	49	42.	42	**13**	27.5	30	14	22.
5	34	39	36.5	39	43	41.	78	**100**	89.	52	49	50.5	34	75	54.5	28	32	30.
6	53	39	46.	48	43	45.5	73	76	74.5	41	47	44.	91	20	55.5	32	14	23.
7	49	36	42.5	47	45	46.	87	58	72.5	49	46	47.5	37	28	32.5	24	21	22.5
8	57	73	65.	50	52	51.	81	56	68.5	47	47	47.	44	25	34.5	25	23	24.
9	57	52	54.5	50	51	50.5	58	34	46.	46	36	41	82	**82**	82.	32	30	31.
10	75	52	63.5	**58**	53	55.5	51	62	56.5	39	46	42.5	85	81	83.	40	29	34.5
11	79	62	70.5	56	53	54.5	65	38	51.5	44	39	41.5	80	75	77.5	28	32	30.
12	70	66	68.	55	**54**	54.5	61	38	49.5	43	43	43.	90	32	61.	30	18	24.
13	62	52	57.	53	53	53.	63	42	52.5	48	46	47.	68	24	46.	30	19	24.5
14	**84**	56	70.	57	**54**	55.5	60	31	45.5	48	36	42	30	61	45.5	23	43	33.
15	73	53	63.	52	48	50.	48	33	40.5	44	39	41.5	30	19	24.5	23	24	23.5
16	82	43	62.5	51	46	48.5	72	73	72.5	50	51	50.5	**92**	54	73.	41	33	37.
17	36	34	35.	42	40	41.	62	40	51.	46	40	43.	54	23	38.5	33	25	29.
18	31	16	23.5	34	26	30.	65	24	44.5	44	35	39.5	42	23	32.5	31	25	28.
19	**19**	24	21.5	**22**	31	26.5	72	45	58.5	49	47	48.	51	**13**	32.	29	17	23.
20	26	34	30.	26	38	32.	49	42	45.5	45	48	46.5	**19**	24	21.5	20	27	23.5
21	38	21	29.5	39	32	35.5	56	65	60.5	47	53	50.	27	24	25.5	23	23	23.
22	35	24	29.5	36	37	36.5	82	37	59.9	51	41	46.	21	19	20.	16	22	19.
23	37	64	50.5	41	51	46.	73	56	64.5	51	47	49.	27	33	30.	24	29	26.5
24	48	43	45.5	44	46	45.	75	35	55.	45	39	42.	52	27	39.5	30	28	29.
25	60	40	50.	49	49	49.	61	27	44.	43	28	35.5	37	21	29.	24	20	22
26	68	**13**	40.5	49	26	37.5	45	24	34.5	**35**	**31**	33.	50	26	38.	27	28	27.5
27	36	15	25.5	38	**25**	31.5	47	**100**	73.5	42	55	48.5	30	27	28.5	27	24	25.5
28	44	15	29.5	47	**25**	36.	73	58	65.5	**52**	51	51.5	59	30	44.5	33	29	31.
29	61	48	54.5	52	44	48.	69	36	52.5	51	43	47.	52	20	36.	24	**11**	17.5
30	62	**75**	68.5	46	45	45.5	38	61	49.5	43	52	47.5	24	41	32.5	19	38	28.5
31	81	67	74.	45	48	46.5	73	**100**	86.5	**52**	**57**	54.5						
Sum.	1705	1326	1515.5	1397	1320	1358.5	1960	1587	1773.5	1409	1359	1384.0	1519	1080	1294.0	876	788	832.0
Mean.	55.0	42.8	48.9	45.0	42.6	43.8	63.2	51.2	57.2	45.5	43.9	44.7	50.6	35.6	43.1	29.2	26.2	27.7

TABLE III.—*Per Cent. of Saturation of the Air and Temperature of the Dew Point.*

Date	OCTOBER						NOVEMBER						DECEMBER					
	RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT		
	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.
1							80	89	84.5	28	29	28.5	71	61	66.	14	14	14.
2							67	37	52.	21	12	16.5	71	81	76.	14	10	12.
3							36	**20**	28.	15	11	13.	**100**	67	83.5	4	—7	—1.5
4							52	62	57.	23	30	26.5	51	53	52.	4	14	9.
5							80	28	54.	28	10	19.	33	**100**	66.5	6	8	7.
6							**32**	26	29.	17	16	16.5	70	60	65.	—5	2	—1.5
7							37	**100**	68.5	24	20	22.	66	81	73.5	8	9	8.5
8							82	**100**	91.	11	0	5.5	64	54	59.	—10	**—18**	—14.
9							67	78	72.5	—7	5	—1.	**100**	54	77.	**—21**	**—18**	—19.5
10							85	**100**	92.5	16	30	23.	**100**	60	80.	—10	—13	—11.5
11							74	81	77.5	—1	10	4.5	56	55	55.5	—16	—3	—9.5
12							64	81	72.5	**—10**	10	0.	47	**100**	73.5	1	0	.5
13							**100**	75	87.5	3	**0**	1.5	78	**40**	59.	5	8	6.5
14							78	56	67.	5	8	6.5	47	66	56.5	—1	8	3.5
15							48	40	44.	8	17	12.5	70	64	67.	—5	7	1.
16							69	**100**	84.5	11	19	15.	64	48	56.	7	9	8.
17							74	90	82.	19	**31**	25.	**17**	64	40.5	4	7	5.5
18	54	79	66.5	22	27	24.5	82	66	74.	**31**	27	29.	71	84	77.5	—4	16	6.
19	**100**	85	92.5	24	16	20.	54	45	49.5	22	22	22.	82	88	85.	11	**25**	18.
20	57	61	59.	**9**	14	11.5	66	**100**	83.	27	2	14.5	51	77	64.	12	22	17.
21	61	36	48.5	14	**10**	12.	**100**	76	88.	—2	1	—.5	**100**	76	88.	13	2	7.5
22	57	43	50.	24	28	26.	51	66	58.5	3	8	5.5	57	**100**	78.5	—1	13	6.
23	39	54	46.5	23	26	24.5	81	57	69.	9	9	9.	**100**	74	87.	3	—1	1.
24	**100**	**100**	100.	**27**	21	24.	79	83	81.	6	13	9.5	58	78	68.	0	5	2.5
25	**19**	50	34.5	12	17	14.5	63	45	54.	4	6	5.	58	58	58.	11	11	11.
26	38	20	29.	16	11	13.5	79	75	77.	6	20	13.	78	68	73.	21	23	22.
27	45	38	41.5	18	19	18.5	73	56	64.5	16	17	16.5	88	69	78.5	**25**	24	24.5
28	34	88	61.	15	25	20.	88	72	80.	25	15	20.	66	48	57.	21	21	21.
29	83	**100**	91.5	13	**29**	21.	72	**100**	86.	15	28	21.5	**100**	**100**	100.	18	4	11.
30	28	24	26.	10	19	14.5	69	72	70.5	11	15	13.	**100**	**100**	100.	10	2	6.
31	24	**16**	20.	15	11	13.							**100**	74	87.	5	—1	—3.
Sum.	739	794	766.5	242	273	257.5	2082	2076	2079	384	441	412.5	2214	2202	2208	134	203	168.5
Mean	52.8	56.7	54.7	17.3	19.5	18.4	69.4	69.2	69.3	12.8	14.7	13.7	71.4	71.	71.2	4.3	6.5	5.4

TABLE IV. *Weekly Means of Soil Temperatures.*

WEEK ENDING.	AIR TEMP	DEPTH					
		3 INCHES	6 INCHSS	12 INCHES	24 INCHES	36 INCHES	72 INCHES
January 7	22.2	22.7	24.3	26.4	29.1	32.0	39.3
January 14	15.1	20.0	22.8	27.0	29.1	31.8	38.3
January 21	10.1	15.8	19.0	22.6	25.8	29.6	37.4
January 28	10.0	13.9	16.2	20.3	23.9	27.8	36.1
February 4	10.1	23.1	23.5	24.4	25.4	27.3	35.3
February 11	24.9	27.1	27.8	27.7	28.1	29.4	35.9
February 18	23.2	27.6	28.5	28.7	29.2	30.3	35.0
February 25	25.0	26.6	28.0	28.4	29.8	31.0	35.0
March 4	28.6	33.3	33.9	32.4	31.8	32.0	35.0
March 11	26.6	32.4	33.1	33.0	33.2	33.8	35.0
March 18	24.5	30.4	32.1	32.2	32.8	34.0	35.8
March 25	19.9	28.9	30.8	31.1	32.3	33.8	36.0
April 1	21.5	30.9	32.9	32.6	32.6	33.6	36.0
April 8	30.3	35.7	36.0	35.4	34.9	34.8	36.0
April 15	42.4	45.4	44.9	41.6	39.6	38.3	36.4
April 22	42.9	46.1	47.0	46.9	44.5	41.9	37.6
April 29	44.2	48.1	49.9	47.2	45.4	43.1	39.1
May 6	29.9	38.6	40.4	42.1	42.9	43.5	40.2
May 13	45.8	48.4	49.4	48.6	45.8	43.6	41.0
May 20	43.6	44.4	45.7	47.3	46.9	46.1	41.0
May 27	51.2	51.1	51.2	51.0	48.7	47.1	42.0
June 3	53.7	56.6	57.4	55.9	52.9	49.7	43.4
June 10	47.4	55.9	56.7	56.7	55.1	52.3	44.2
June 17	58.1	58.9	59.6	58.5	56.1	53.9	46.2
June 24	64.5	66.6	67.6	...	61.6	57.9	47.6
July 1	65.5	69.6	71.0	69.1	64.9	60.9	49.6
July 8	62.9	69.1	70.5	70.1	64.1	62.7	51.4
July 15	65.4	70.4	72.3	71.0	66.9	63.8	52.8
July 22	65.1	69.7	71.1	70.8	66.9	64.3	53.9
July 29	67.0	69.9	71.9	71.2	67.1	64.4	54.7
August 5	57.8	68.6	70.8	69.1	67.3	65.1	55.3
August 12	51.1	64.3	67.5	67.4	64.9	63.5	55.0
August 19	62.8	69.2	71.5	70.6	68.4	64.2	56.0
August 26	61.7	67.8	71.1	70.6	66.9	65.0	56.0
September 2	62.3	66.3	67.5	68.8	66.9	63.5	56.6
September 9	46.6	56.0	61.6	63.6	63.0	62.6	56.1
September 16	43.9	66.0	59.2	59.6	58.1	58.3	55.4
September 23	55.1	58.7	60.7	60.9	58.4	57.9	54.9
September 30	50.6	54.4	58.2	59.6	58.4	58.0	54.0
October 7	37.7	44.2	49.7	52.4	54.1	55.3	53.6
October 14	42.2	44.9	48.6	50.7	50.9	52.4	52.4
October 21	25.1	35.8	40.7	45.9	48.2	49.1	51.0
October 28	33.8	35.0	36.9	40.0	41.9	45.1	49.0
November 4	31.6	30.2	38.5	40.6	41.2	45.4	47.7
November 11	20.3	31.6	33.9	38.7	40.6	42.8	48.7
November 18	19.5	25.7	27.4	32.5	25.3	39.3	45.4
November 25	16.6	25.9	27.7	31.6	34.2	37.8	44.3
December 2	21.1	24.4	25.3	28.9	31.7	35.3	42.6
December 9	5.1	15.3	19.1	23.2	28.8	33.1	41.0
December 16	7.6	11.3	14.4	19.1	24.1	29.2	39.1
December 23	13.1	16.7	18.3	21.9	24.4	28.0	37.6
December 30	18.1	20.8	20.9	23.3	24.9	27.7	36.2
Sums	1928.3	2198.3	2305.0	2289.2	2330.0	2353.3	2313.2
Means	37.1	42.3	44.3	44.0	44.8	45.3	44.5

TABLE V.—*Atmospheric Pressure.*

Date.	JANUARY			FEBRUARY			MARCH			APRIL		
	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.
1	**23.324**	**23.250**	23.287	23.107	23.157	23.132	23.031	23.115	23.073	23.172	23.204	23.188
2	23.214	23.086	23.150	**23.243**	23.157	23.200	**23.149**	**23.145**	23.147	22.984	22.770	22.877
3	23.024	23.071	23.047	23.015	22.843	22.929	23.033	22.947	22.990	22.670	23.092	22.881
4	23.038	23.027	23.047	22.935	23.155	23.045	22.917	22.917	22.917	**23.180**	23.119	23.149
5	22.999	23.039	23.019	23.121	23.017	23.069	22.875	22.989	22.932	23.108	23.105	23.106
6	22.961	22.673	22.817	22.925	22.911	22.918	23.073	23.081	23.077	23.015	22.861	22.938
7	22.675	22.801	22.738	22.931	22.863	22.897	23.071	22.975	23.023	22.862	22.953	22.907
8	22.789	22.731	22.760	22.833	22.933	22.883	22.869	22.837	22.853	23.035	23.083	23.059
9	22.744	22.754	22.749	23.033	23.049	23.041	22.731	22.731	22.731	23.163	23.183	23.173
10	22.622	22.729	22.675	22.997	22.989	22.993	22.685	22.725	22.705	23.101	23.021	23.061
11	22.668	22.623	22.645	23.057	23.119	23.088	22.749	22.715	22.732	23.019	23.115	23.067
12	22.777	22.867	22.822	23.061	23.087	23.074	22.749	22.689	22.719	**23.272**	**23.265**	23.268
13	22.870	22.821	22.845	23.218	23.044	23.131	22.564	**22.472**	22.518	23.229	23.121	23.175
14	22.907	22.945	22.926	22.897	22.991	22.944	**22.374**	22.548	22.461	23.125	23.039	23.082
15	22.984	23.032	23.008	22.981	22.887	22.934	22.559	22.737	22.648	23.051	22.945	22.998
16	22.884	22.842	22.868	**22.665**	**22.556**	22.611	22.861	22.897	22.879	22.891	22.829	22.860
17	22.828	22.839	22.833	22.763	22.769	22.766	22.927	22.767	22.847	22.935	22.915	22.925
18	22.942	22.951	22.946	22.743	22.763	22.753	22.667	22.763	22.715	22.993	23.001	22.997
19	22.813	22.781	22.797	22.803	23.082	22.942	22.923	22.809	22.866	23.131	23.085	23.108
20	22.801	22.877	22.839	23.100	23.094	23.097	22.829	22.784	22.806	23.015	22.871	22.943
21	22.905	22.847	22.876	22.942	22.875	22.908	22.673	22.600	22.637	22.771	23.011	22.891
22	22.712	22.710	22.711	23.049	22.994	23.022	22.806	22.907	22.856	23.039	23.093	23.066
23	22.620	**22.567**	22.593	23.051	23.045	23.048	22.959	22.939	22.949	23.095	23.135	23.115
24	**22.603**	22.707	22.657	23.019	22.961	22.990	22.913	22.789	22.851	23.249	23.231	23.240
25	22.873	22.964	22.918	22.897	22.997	22.947	22.685	22.660	22.673	23.249	23.219	23.234
26	22.976	22.951	22.963	23.061	23.123	23.092	22.663	22.767	22.715	23.159	22.977	23.060
27	23.025	22.967	22.996	23.209	23.169	23.189	22.881	22.848	22.864	23.057	23.081	23.069
28	23.073	23.059	23.066	23.023	23.015	23.019	22.854	22.983	22.918	23.007	22.637	22.822
29	22.835	22.931	22.883				23.051	23.106	23.079	22.629	**22.601**	22.615
30	23.034	23.080	23.057				23.048	22.962	23.005	22.741	22.907	22.824
31	23.103	23.204	23.153				22.940	23.006	22.973			
Sum.	709.658	709.726	709.692	643.679	643.645	643.662	708.109	708.210	708.159	690.945	690.469	690.707
Mean.	22.892	22.927	22.893	22.988	22.987	22.988	22.842	22.844	22.843	23.031	23.015	23.023

TABLE V. (Continued).—*Atmospheric Pressure.*

Date.	MAY			JUNE			JULY			AUGUST		
	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.
1	22.934	22.966	22.950	23.024	22.881	22.953	22.967	22.945	22.956	23.063	23.085	23.074
2	22.935	22.934	22.934	**22.880**	**22.765**	22.822	23.176	23.239	23.207	23.131	23.069	23.100
3	22.992	23.084	23.038	22.980	23.111	23.046	23.230	23.199	23.215	23.121	**22.930**	23.025
4	23.024	22.973	22.909	23.223	**23.277**	23.250	23.230	23.103	23.166	23.055	23.089	23.072
5	23.059	**23.215**	23.137	**23.253**	23.173	23.213	23.097	23.059	23.078	23.173	23.139	23.156
6	**23.255**	23.113	23.184	23.164	23.115	23.140	23.154	23.147	23.151	23.151	23.195	23.173
7	23.009	22.965	22.987	23.153	23.137	23.145	23.210	23.185	23.198	23.283	**23.295**	23.289
8	23.077	23.079	23.078	23.193	23.127	23.160	23.269	23.227	23.248	23.283	23.197	23.240
9	23.159	23.133	23.146	23.099	23.007	23.053	23.258	23.229	23.243	23.281	23.247	23.264
10	23.191	23.107	23.149	22.984	22.955	22.969	23.230	23.171	23.200	23.275	23.263	23.269
11	23.063	23.043	23.053	22.979	22.997	22.988	23.232	23.233	23.233	**23.285**	23.249	23.267
12	23.009	22.983	22.996	23.006	23.057	23.032	23.239	23.207	23.223	23.265	23.201	23.233
13	22.937	22.913	22.925	23.124	23.047	23.085	23.230	23.175	23.202	23.225	23.187	23.206
14	22.909	22.869	22.889	23.156	23.121	23.139	23.194	23.143	23.169	23.169	23.181	23.175
15	22.877	22.921	22.899	23.158	23.139	23.148	23.150	23.137	23.143	23.201	23.149	23.175
16	22.955	22.845	22.900	23.130	23.155	23.143	23.094	22.955	23.025	23.215	23.171	23.193
17	22.809	**22.707**	22.758	23.201	23.257	23.229	**22.964**	22.957	22.960	23.181	23.139	23.160
18	22.751	22.763	22.757	23.234	23.223	23.229	23.025	**22.927**	22.976	23.179	23.093	23.136
19	**22.725**	22.709	22.717	23.164	23.059	23.111	23.058	23.087	23.072	23.187	23.194	23.190
20	22.779	22.917	22.848	23.034	22.981	23.007	23.107	23.105	23.106	23.233	23.171	23.202
21	23.061	23.071	23.066	23.040	22.959	23.000	23.157	23.153	23.155	23.159	23.097	23.128
22	23.107	22.819	22.963	23.036	22.995	23.015	23.259	23.191	23.225	23.075	23.191	23.133
23	22.947	22.769	22.858	23.014	23.059	23.037	23.243	23.253	23.248	23.200	23.151	23.175
24	22.867	22.999	22.933	23.140	22.995	23.068	**23.324**	23.295	23.309	23.223	23.221	23.222
25	23.050	23.007	23.028	23.012	22.931	22.971	23.286	23.161	23.224	23.284	23.172	23.228
26	22.987	22.961	22.974	23.039	23.069	23.054	23.184	23.108	23.146	23.284	23.163	23.223
27	22.933	22.853	22.893	23.140	23.091	23.115	23.112	23.109	23.111	23.197	23.172	23.185
28	22.781	22.801	22.836	23.082	23.045	23.033	23.155	23.079	23.117	23.109	23.172	23.141
29	23.073	23.027	23.050	23.088	22.959	23.024	23.166	23.117	23.142	23.199	23.054	23.126
30	22.899	22.873	22.886	22.906	22.788	22.847	23.114	23.135	23.125	**23.047**	22.954	23.001
31	23.039	22.963	23.001				23.279	23.083	23.181	23.055	23.029	23.042
Sum.	712.223	711.442	711.832	692.696	691.445	692.071	718.383	717.124	717.754	718.783	717.619	718.203
Mean.	22.975	22.940	22.932	23.090	23.048	23.069	23.174	23.133	23.152	23.186	23.140	23.168

TABLE V. (Concluded.)--*Atmospheric Pressure.*

Date.	SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER		
	7 a m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.	7 a. m.	7 p. m.	Mean.
1	22.997	23.075	23.036	**22.624**	**22.699**	22.661	23.018	23.151	23.084	22.953	22.941	22.947
2	23.023	23.047	23.035	22.871	23.003	22.937	23.136	23.181	23.158	22.677	23.053	22.865
3	23.039	23.035	23.037	23.004	22.915	22.960	22.975	22.867	22.921	23.219	23.174	23.197
4	23.051	22.987	23.019	23.039	23.193	23.116	22.841	22.885	22.863	23.098	23.040	23.069
5	23.013	23.135	23.074	22.943	23.157	23.050	23.101	**23.200**	23.150	22.927	23.121	23.024
6	23.223	23.335	23.279	23.065	23.157	23.111	23.019	22.833	22.925	23.185	23.179	23.182
7	23.273	23.151	23.212	23.121	23.221	23.171	22.841	22.921	22.881	23.045	23.001	23.023
8	23.165	23.066	23.115	23.233	23.077	23.155	22.924	23.100	23.012	23.163	23.293	23.228
9	23.248	23.273	23.262	22.815	22.929	22.872	23.195	23.150	23.173	**23.311**	23.293	23.302
10	**23.400**	**23.408**	23.404	22.957	23.123	23.040	23.023	22.951	22.987	23.232	23.084	23.158
11	23.398	23.300	23.334	23.195	23.075	23.135	22.986	23.057	23.022	22.953	22.997	22.975
12	23.100	22.960	23.030	23.127	23.185	23.156	23.000	23.030	23.015	23.025	23.062	23.044
13	22.985	23.037	23.011	23.235	23.177	23.206	23.126	23.192	23.159	23.058	23.035	23.054
14	23.020	23.023	23.022	23.087	22.931	23.009	**23.222**	23.132	23.177	23.051	23.021	23.036
15	23.003	22.994	23.043	22.837	22.977	22.907	22.986	22.861	22.924	22.997	23.091	23.044
16	23.155	23.144	23.150	23.157	23.253	23.205	22.835	22.861	22.848	23.069	23.059	23.034
17	23.191	23.193	23.192	23.219	22.951	23.085	22.775	22.815	22.795	23.067	23.053	23.065
18	23.229	23.183	23.206	22.885	22.839	22.862	22.919	22.957	22.938	22.998	22.993	22.997
19	23.181	23.107	23.144	22.949	23.083	23.016	22.881	22.711	22.796	22.895	22.997	22.946
20	23.079	23.009	23.044	23.087	23.127	23.107	**22.470**	22.769	22.619	22.847	22.768	22.803
21	23.023	23.003	23.013	23.122	23.073	23.097	22.959	22.972	22.966	22.805	22.993	22.899
22	23.006	22.999	23.002	23.017	22.965	22.991	22.879	22.897	22.888	22.949	22.955	22.952
23	22.933	23.043	22.988	22.853	22.913	22.883	22.883	22.840	22.862	23.139	23.200	23.169
24	23.109	23.131	23.120	23.041	23.319	23.180	22.858	23.044	22.951	23.258	**23.238**	23.278
25	23.241	23.253	23.247	**23.333**	23.315	23.349	23.062	23.148	23.105	23.176	23.108	23.142
26	23.292	23.177	23.234	23.209	22.963	23.086	23.094	22.848	22.971	23.135	23.178	23.157
27	23.105	22.933	23.019	23.009	23.013	23.011	22.966	22.792	22.879	23.124	23.134	23.129
28	22.999	22.879	22.939	22.987	23.151	23.069	22.685	22.846	22.766	22.908	**22.710**	22.809
29	22.945	23.005	22.975	23.275	**23.327**	23.301	22.819	**22.627**	22.723	**22.652**	22.815	22.734
30	**22.915**	**22.707**	22.811	23.293	23.121	23.207	22.823	22.912	22.867	22.917	22.955	22.936
31				22.981	22.887	22.934				23.053	23.071	23.062
Sum.	693.402	692.592	692.998	714.620	715.119	714.369	688.312	688.550	688.431	713.898	714.683	714.290
Mean.	23.113	23.086	23.099	23.052	23.067	23.060	22.943	22.951	22.947	23.029	23.054	23.041

Table VI.—*Wind.*

JANUARY.							FEBRUARY.						
Date.	DIRECTION FROM.			Daily distance in miles.	Greatest number of mi. in any one hour of day.	Maximum velocity in miles per hour.	Date.	DIRECTION FROM.			Daily distance in miles.	Greatest number of mi. in any one hour of day.	Maximum velocity in miles per hour.
	7 a.m.	Noon.	7 p m.					7 a.m.	Noon.	7 p.m.			
1	n	ne	se	73	9	16	1	se	n	ne	236	20	23
2	s	s	sc	167	11	17	2	se	se	sw	218	22	24
3	s	nw	n	324	22	26	3	sw	sw	w	226	26	31
4	n	n	se	206	20	28	4	nw	n	w	438	19	32
5	s	se	sw	152	11	16	5	sw	w	sw	500	26	37
6	se	s	s	353	**30**	**37**	6	sw	sw	sw	441	22	36
7	sw	s	s	348	29	36	7	s	sw	s	356	20	31
8	s	s	s	312	19	28	8	sw	sw	n	309	19	25
9	e	sw	e	252	21	24	9	nw	nw	e	283	26	29
10	s	sw	s	431	**30**	36	10	n	n	n	156	9	14
11	se	n	ne	263	21	28	11	e	s	e	237	24	33
12	n	ne	e	242	16	18	12	sw	sw	w	247	19	25
13	se	sw	ne	173	11	16	13	se	s	sw	345	19	33
14	n	n	ne	218	19	21	14	nw	w	nw	536	**33**	40
15	s	sw	nw	152	16	17	15	w	sw	nw	**548**	27	42
16	se	sw	n	173	28	30	16	sw	sw	sw	414	29	38
17	n	n	ne	264	20	24	17	ne	nw	e	494	35	39
18	s	sw	s	195	12	24	18	s	n	w	302	22	26
19	sw	sw	nw	223	22	25	19	w	nw	nw	343	21	24
20	se	ne	nw	288	22	26	20	s	sw	sw	318	28	**46**
21	se	ne	se	132	13	14	21	ne	sw	sw	192	14	20
22	w	n	w	162	15	20	22	n	w	ne	273	26	31
23	sw	n	ne	264	18	28	23	se	n	nw	274	22	26
24	ne	n	nw	240	20	21	24	se	sw	sw	208	15	20
25	ne	sw	n	212	13	17	25	sw	w	w	296	22	24
26	s	sw	sw	148	15	19	26	se	nw	ne	265	21	31
27	sw	s	sw	**527**	24	36	27	ne	w	e	191	15	20
28	sw	s	s	410	24	33	28	sw	nw	nw	162	14	26
29	sw	w	nw	203	17	21							
30	sw	s	sw	353	26	36							
31	sw	n	n	362	19	28							
Sum.				7812			Sum.				8809		
Daily mean.				252			Daily mean.				314.6		
Hourly mean.				10.5			Hourly mean.				13.1		

TABLE VI. (Continued).—*Wind.*

MARCH.							APRIL.						
	DIRECTION FROM.							DIRECTION FROM.					
Date.	7 a.m.	Noon.	7 p.m.	Daily distance in miles.	Greatest number of mi. in any one hour of day.	Maximum velocity in miles per hour.	Date.	7 a.m.	Noon.	7 p.m.	Daily distance in miles.	Greatest number of mi. in any one hour of day.	Maximum velocity in miles per hour.
1	ne	n	ne	383	23	29	1	sw	n	sw	261	24	27
2	nw	n	n	284	26	28	2	s	sw	sw	215	20	24
3	se	sw	n	255	21	27	3	ne	n	n	303	22	32
4	s	sw	sw	182	18	24	4	sw	n	ne	433	34	40
5	s	sw	n	264	15	22	5	s	n	se	183	15	18
6	sw	sw	s	302	20	25	6	s	s	s	282	18	24
7	se	sw	sw	309	24	26	7	sw	w	w	348	24	20
8	sw	sw	ne	425	28	29	8	w	w	nw	411	32	**41**
9	sw	w	ne	533	39	49	9	w	n	sw	429	37	40
10	se	sw	s	360	24	23	10	s	s	se	261	24	28
11	n	sw	sw	182	16	17	11	sw	n	n	217	18	24
12	n	nw	s	232	21	26	12	nw	nw	n	226	21	23
13	sw	sw	sw	318	22	25	13	s	nw	s	387	**38**	41
14	n	nw	nw	426	36	41	14	e	nw	w	256	23	25
15	sw	sw	w	563	29	37	15	s	s	se	232	19	20
16	se	sw	e	407	34	39	16	s	s	ne	117	12	13
17	s	s	se	**622**	**48**	**54**	17	n	s	s	347	34	39
18	sw	sw	sw	387	36	41	18	se	w	nw	97	11	13
19	sw	sw	sw	528	40	43	19	n	n	se	305	30	36
20	sw	sw	s	518	34	36	20	s	nw	s	380	28	30
21	sw	s	ne	368	24	33	21	n	n	n	306	25	34
22	ne	ne	e	502	38	43	22	w	nw	w	326	20	32
23	sw	sw	sw	287	27	29	23	s	n	n	249	18	24
24	se	s	sw	510	30	33	24	s	n	n	306	30	35
25	sw	sw	sw	418	28	34	25	s	n	n	213	20	24
26	sw	sw	e	525	36	36	26	s	sw	sw	272	29	24
27	ne	w	sw	495	38	40	27	n	nw	n	**471**	22	35
28	sw	sw	n				28	s	s	se	400	30	36
29	ne	s	se	136	12	16	29	s	n	n	261	22	26
30	se	sw	sw	151	14	18	30	nw	n	ne	248	20	24
31	s	n	sw	266	19	23							
Sum				11118			Sum.				8742		
Daily mean.				370.6			Daily mean.				291.4		
Hourly mean.				15.4			Hourly mean.				12.1		

TABLE VI. (Continued).—*Wind.*

MAY.

Date.	DIRECTION FROM.			Daily distance in miles.	Greatest number of mi. in any one hour of day.	Maximum velocity in miles per hour.
	7 a m.	Noon.	7 p.m.			
1	ne	n	ne	320	24	32
2	s	s	e			
3	se	s	e	459	29	32
4	se	se	e	606	35	40
5	w	e	se	408	24	28
6	s	s	se	248	20	24
7	s	sw	ne	258	21	23
8	n	nw	se	230	28	37
9	s	s	n			
10	sw	w	w	211	19	21
11	n	nw	e	271	18	20
12	e	ne	n	316	25	32
13	s	s	n	119	18	20
14	s	e	e	169	25	36
15	s	s	se	344	30	33
16	se	se	sw	366	37	41
17	sw	s	sw	522	50	55
18	sw	sw	s	404	21	28
19	s	se	s	244	20	24
20	nw	sw	nw	248	25	39
21	w	sw	sw	455	35	38
22	sw	sw	sw	274	18	21
23	nw	s	s	282	16	20
24	se	se	ne	552	43	53
25	s	sw	w	315	33	36
26	nw	n	nw	219	20	24
27	s	s	s	339	26	30
28	s	sw	w	400	32	38
29	nw	e	se			
30	s	s	sw			
31	w	sw	w	333	25	26
Sum				8922		
Daily mean.				330.4		
Hourly mean.				13.7		

JUNE.

Date.	DIRECTION FROM.			Daily distance in miles.	Greatest number of mi. in any one hour of day.	Maximum velocity in miles per hour.
	7 a.m.	Noon.	7 p.m.			
1	sw	sw	w	321	24	28
2	se	s	s	416	26	29
3	e	sw	sw	401	37	39
4	se	n	ne	262	24	30
5	nw	nw	nw	166	19	24
6	sw	nw	ne	142	13	17
7	sw	ne	se	171	14	18
8	s	nw	e	263	22	25
9	e	e	se	247	21	24
10	e	se	se	203	20	24
11	s	n	n	282	28	36
12	sw	se	ne	209	24	28
13						
14	se	w	ne	220	18	19
15	s	se	s	236	21	27
16	w	nw	e	220	15	19
17	s	nw	sw	162	13	14
18	sw	n	e	214	19	24
19	sw	se	se	252	19	20
20	s	se	s	317	32	36
21	s	sw	e	221	22	38
22	s	sw	se	246	23	25
23	se	sw	sw	238	25	28
24	sw	sw	sw	351	24	28
25	sw	w	w	445	30	36
26	sw	w	w	455	32	38
27	s	w	n	287	20	23
28	sw	nw	sw	210	13	18
29	n	w	nw	306	21	24
30	sw	nw	se	436	35	40
Sum				7899		
Daily mean				272.4		
Hourly mean.				11.3		

TABLE VI. (Continued).—*Wind.*

JULY.

Date.	DIRECTION FROM.			Daily distance in miles.	Greatest number of mi. in any one hour of day.	Maximum velocity in miles per hour.
	7 a.m.	Noon.	7 p.m			
1	n	o	n	461	28	31
2	n	n	ne	252	22	26
3	s	se	se	254	17	20
4	s	o	s	321	23	25
5	sw	w	sw	191	12	16
6	s	o	s	214	18	19
7	s	w	s	137	19	24
8	s	e	se	156	14	23
9	s	se	e	375	32	35
10	s	e	e	213	24	27
11	n	ne	se	230	21	24
12	w	e	s	220	20	22
13	sw	e	e			
14	s	ne	s			
15	s	se	s			
16	s	s	s			
17	sw	w	w			
18	w	w	sw	130	15	18
19	w	o	o	421	28	32
20	se	se	s	543	40	43
21	s	w	sw	197	18	20
22	se	sw	sw	198	18	20
23	sw	se	sw	188	15	17
24	n	s	s	136	13	24
25	sw	se	s	142	22	25
26	s	w	nw	154	16	18
27	o	w	nw	287	25	27
28	se	w	nw	283	25	32
29	se	e	s	200	20	22
30	o	ne	n	120	21	25
31	s	s	s	299	35	53
Sum.				6322		
Daily mean.				243.1		
Hourly mean.				10.1		

AUGUST.

Date.	DIRECTION FROM.			Daily distance in miles.	Greatest number of mi. in any one hour of day.	Maximum velocity in miles per hour.
	7 a.m.	Noon.	7 p.m.			
1	s	sw	n	198	19	21
2	s	sw	o	183	23	25
3	o	sw	o	144	17	18
4	s	se	n			
5	n	ne	n	153	17	27
6	n	sw	o	141	14	24
7	o	sw	o	58	17	34
8	o	se	ne	100	9	13
9	s	s	se	136	13	15
10	s	nw	ne	148	14	18
11	s	nw	ne	175	18	25
12	s	nw	w	116	14	16
13	s	nw	e	164	29	36
14	s	w	n	91	14	20
15	s	w	sw	166	19	21
16	s	s	s	189	22	25
17	s	nw	w	239	24	30
18	se	sw	se	212	18	26
19	se	sw	se	227	21	27
20	sw	s	s	249	19	25
21	sw	sw	se	147	21	30
22	sw	n	n	211	18	19
23	o	s	s	119	14	18
24	se	e	o	153	12	20
25	s	se	e	125	12	15
26	se	ne	s	96	14	17
27	se	sw	se	230	20	24
28	s	ne	ne	146	18	25
29	ne	se	sw	148	17	30
30	e	sw	sw	145	15	18
31	e	sw	sw	242	21	26
Sum.				4854		
Daily mean.				161.8		
Hourly mean.				6.7		

TABLE VI. (Continued).—*Wind.*

SEPTEMBER.

Date.	DIRECTION FROM.			Daily distance in miles.	Greatest number of mi. in any one hour of day.	Maximum velocity in miles per hour.
	7 a.m.	Noon.	7 p.m.			
1	e	s	e	177	17	20
2	sw	sw	s	182	19	24
3	sw	w	s	415	32	38
4	sw	w	se	240	22	25
5	sw	e	ne	248	24	30
6	sw	e	ne	301	32	41
7	n	n	se	236	18	20
8	n	s	n	168	19	24
9	s	n	s	438	39	45
10	n	n	n	244	23	25
11	e	s	e	227	17	23
12	s	s	ne	144	12	14
13	se	s	s	168	20	22
14	s	w	s	245	26	30
15	n	w	w	250	25	28
16	nw	s	se	346	28	31
17	nw	s	se	161	12	13
18	se	e	s	123	10	14
19	s	s	e	106	12	14
20	se	s	w	226	20	24
21	se	sw	s	167	14	17
22	w	s	s	201	17	20
23	w	w	e	268	28	33
24	w	nw	e	179	19	21
25	s	w	e	184	17	20
26	w	s	n	97	16	19
27	sw	sw	se	171	28	33
28	sw	s	s	235	28	34
29	w	w	s	486	29	33
30	e	se	se	302	20	34
Sum.				6935		
Daily mean.				231.2		
Hourly mean.				9.6		

OCTOBER.

Date.	DIRECTION FROM.			Daily distance in miles.	Greatest number of mi. in any one hour of day.	Maximum velocity in miles per hour.
	7 a.m.	Noon.	7 p.m.			
1	s	sw	w	541	51	54
2	w	w	nw	549	47	52
3	se	se	w	700	47	51
4	nw	nw	nw	427	34	42
5	se	n	se	273	24	27
6	sw	sw	ne	186	15	17
7	se	se	e	500	29	36
8	sw	sw	se	136	21	23
9	s	s	sw	409	40	48
10	s	sw	sw	431	32	35
11	sw	sw	sw	387	23	28
12	w	nw	se	398	24	32
13	n	nw	sw	197	20	33
14	se	sw	se			
15	w	nw	nw	363	28	32
16	o	o	o	203	24	27
17	o	nw	w	117	30	32
18	sw	nw	n	254	33	35
19	nw	nw	nw	284	20	24
20	se	nw	w	322	22	25
21	se	w	sw	212	28	32
22	s	sw	o	241	21	25
23	sw	w	w	246	26	30
24	w	w	n	390	30	40
25	o	w	e	170	31	36
26	s	sw	w	229	22	26
27	w	w	s	385	26	29
28	s	nw	o	354	29	32
29	o	o	o	121	23	28
30	e	w	sw	180	18	21
31	se	w	w	372	33	48
Sum.				9577		
Daily mean.				319.2		
Hourly mean.				13.3		

TABLE VI. (Concluded) —*Wind.*

NOVEMBER

Date	DIRECTION FROM			Daily distance in miles.	Greatest number of mi. in any one hour of day	Maximum velocity in miles per hour.
	7 a.m.	Noon	7 p.m.			
1	w	w	s	340	35	40
2	w	w	w	213	18	20
3	w	w	w	345	31	38
4	w	w	w	530	48	60
5	w	w	nw	647	49	57
6	s	sw	sw	370	32	37
7	nw	nw	n	570	40	44
8	s	s	se	476	39	42
9	o	o	s			
10	s	sw	se	196	22	27
11	sw	nw	s	86	28	32
12	s	n	sw	67	8	12
13	ne	n	nw	90	10	18
14	se	se	s	151	10	14
15	se	sw	sw	228	20	26
16	sw	nw	sw	338	35	39
17	sw	sw	w	320	30	32
18	w	w	sw	560	30	45
19	sw	w	sw	440	36	38
20	s	n	nw	542	40	46
21	nw	nw	sw	600	36	39
22	sw	w	sw	481	30	33
23	s	sw	sw	286	21	25
24	w	n	n	174	23	30
25	sw	sw	ne	211	23	26
26	se	s	ne	224	28	31
27	n	nw	w	198	24	27
28	w	nw	w	476	35	39
29	sw	s	s	406	25	30
30	w	w	w	347	22	26
Sum				9912		
Daily mean				341.8		
Hourly mean				14.2		

DECEMBER.

Date	DIRECTION FROM			Daily distance in miles.	Greatest number of mi. in any one hour of day	Maximum velocity in miles per hour.
	7 a.m.	Noon	7 p.m.			
1	w	w	sw	394	30	34
2	w	w	w	493	31	36
3	nw	w	sw	550	32	35
4	w	w	s	327	20	24
5	sw	w	w	458	29	33
6	e	w	w	266	22	26
7	w	w	n	307	22	25
8	n	nw	s	207	22	24
9	s	s	s	76	11	14
10	e	s	w	59	4	9
11	s	s	s	48	4	8
12	s	nw	ne	150	15	16
13	s	se	s	105	11	13
14	sw	sw	se	318	22	25
15	se	ne	se	107	13	17
16	s	w	w	201	23	25
17	w	sw	nw	228	20	25
18	s	se	n	82	14	18
19	se	sw	sw	139	13	24
20	ne	w	s	473	30	36
21	nw	nw	sw	290	20	28
22	sw	w	nw	383	25	30
23	nw	se	n	214	21	26
24	sw	ne	sw	255	23	26
25	sw	sw	sw	287	22	26
26	sw	sw	sw	417	25	29
27	w	w	sw	397	20	27
28	s	w	se	466	29	36
29	sw	ne	e	422	31	37
30	n	nw	s	257	24	28
31	w	w	sw	212	18	
Sum				8669		
Daily mean				279.6		
Hourly mean				11.6		

TABLE VII.—*Precipitation and Evaporation, (in inches), Laramie, Wyo.*

MONTH.	1891		1892		1893		1894		1895		1896		1897		1898	
	Rainfall	Evaporation	Rainfall	Evaporation	Rainfall	Evaoration	Rainfall	Evaporation	Rainfall	Evaporation	Rainfall	Evaporation	Rainfall	Evaporation	Rainfall	Evaporation
January	70	. . .	.01	. . .	T	. . .	.03	. . .	.08	. . .	.44	. . .	.39	. . .	.05	. . .
February	.375	. . .	.36	. . .	.11	. . .	.10	. . .	.14	. . .	.17	. . .	.16	. . .	.01	. . .
March	1.50	. . .	.52	. . .	.29	†	.29	. . .	.43	. . .	.59	. . .	3.97	. . .	.40	. . .
April	.25	. . .	.19	*	.32	24thto 30th .562	1.51	28th to 30th .903	.87	17thto 30th 2.530	3.53	. . .	.55	24thto 30th 1.80	1.28	15thto 30th 3.44
May	2.92	. . .	1.16	24thto 31st 1.59	.33	4.801	.42	6.060	2.09	7.334	.48	. . .	1.85	7.43	1.88	4.60
June	.91	. . .	3.97	8.23	.54	7.884	.64	7.492	2.12	6.236	.72	7.79	.72	7.73	.90	‡10.33
July	1.20	22d to 31st 4.424	2.22	9.19	.34	9.352	1.41	6.000	2.71	7.294	1.66	8.34	1.29	7.00	.65	8.37
August	1.76	8.590	.14	8.27	1.08	6.586	1.26	6.276	1.17	6.033	89	6.09	1.11	7.33	1.16	6.93
September	1.80	5.040	T	6.10	.39	6.015	1.60	6.433	.18	4.944	1.16	4.84	.32	4.84	T	5.68
October	.30	3.720	3.96	1st to 10 th 1.50	.28	2.883	.09	3.303	.74	2.616	.18	to 22d 2.00	.55	to 23th 4.38	.48	to 15th 2.05
November	1.095	1st to 11th .926	T	. . .	.06	. . .	.05	. . .	.32	. . .	.09	. . .	.33	. . .	.61	. . .
December	1.11	. . .	.20	. . .	.10	. . .	.23	. . .	.33	. . .	. . .	. . .	.75	. . .	.23	. . .
Total	13.92	22.7	12.73	34.88	3.84	38.087	7.63	37.168	11.15	37.020	10.75	29.06	11.99	40.51	7.63	41.40

*Evaporation between November 11 and May 24 was 9.69 inches—liable to considerable error.

†From October 1, 1892, to October 1, 1893, evaporation was, apparently, 45.305 inches.

‡An exceptionally dry and windy month.

UNIVERSITY OF WYOMING.

Agricultural College Department.

WYOMING EXPERIMENT STATION,

LARAMIE, WYOMING.

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SEPTEMBER, 1898.

CULTIVATED SHADE AND FOREST TREES.

BY B. C. BUFFUM.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyo.

Wyoming Agricultural Experiment Station.

UNIVERSITY OF WYOMING.

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SILVER SPRUCE ON THE GROUNDS OF EDWARD IVINSON, LARAMIE.

Cultivated Shade and Forest Trees.

B. C. BUFFUM.

Our mountains are covered with vast forests, while our plains and even our river valleys are practically treeless. Belts, groves and scattering specimens of cottonwood, boxelder, willow and alder are found along our streams for ten or twenty miles below where they leave the mountain range but farther down trees of any kind are generally absent or infrequent. At high altitudes the banks of the smaller streams and even those of the large rivers where they course through the mountain parks and valleys, frequently support no tree growth. At lower altitudes in the northern, central and eastern portions of the state small streams are often fringed with boxelder, occasionally a green ash is found and here and there a variety of bushes. In the extreme north-eastern part of the state there are some good-sized oak and birch trees. That there are no trees along the lower courses of our streams where the conditions of moisture are favorable has often been remarked, but as far as I know has not been explained. Undoubtedly the protection afforded by the mountains favors the growth of trees near them, but the same species thrive when planted upon irrigated uplands farther away. Small willows are commonly found the whole length of the stream. Our observations indicate that cottonwoods either will not live or that they make poor growth upon soils which contain large amounts of alkali salts. Willows which rapidly grow into trees will succeed better than any other species on alkali ground. The absence of trees away from the streams is easily explained by the

—(2)

lack of sufficient moisture. Sagebrush is found almost everywhere and in certain localities where conditions of moisture and exposure favor its growth it actually attains the size and height of trees. Ordinarily it remains from six inches to two and one-half feet high.

It is not our purpose here to discuss the native forests of pine and spruce further than to briefly state their extent, the danger of their extinction, and the necessity of their preservation. It is estimated that approximately one-sixth the area of the state, or about 10,000,000 acres of land within our borders, is covered with timber. All this is in the mountain regions and forms great natural storage reservoirs which catch the snows of winter and hold them till late spring and early summer, giving a steady supply of water when most needed to irrigate growing crops in the valleys and on the plains below. Every year fires started, either accidentally or purposely, burn over thousands of acres of these forests. Irrigation is the life of our agriculture, and its future welfare in this state largely depends upon the proper care and management of the native forests. In addition they supply native lumber and an abundance of timber for buildings, fences and wood. Although we have these great mountain forests, a class of vegetation greatly needed upon our irrigated farms and ranches is trees. Man's power to mitigate the bad effects of climate and sudden changes of weather upon himself or the animals and plants useful to him is constantly increasing. He can overcome effects of weather in various ways but his ability to modify climate is limited. He builds houses and barns to shelter himself and his domestic animals, and glass houses in which to grow the tender plants. By planting trees, he provides a grateful shelter to himself and his live stock and provides conditions under which many plants can be made to succeed, which would not otherwise

CATTLE NEAR A NATURAL SHELTER-BELT OF COTTONWOODS.

grow at all. Shelter belts to protect animals from winds and storms are invaluable to the stockman. Protection from the cold saves dollars and cents in the value of the food which would be consumed merely to keep them warm. Upon large ranches where there is more stock than it is possible to provide buildings for, sufficient shelter belts often prevent heavy losses from exposure during storms. A good tree shelter of native cottonwoods is shown in the illustration which was made from a photograph taken on the Wyoming Hereford Ranch east of Cheyenne. We reproduce the cut through the courtesy of the Secretary of State, C. W. Burdick.

The influence of trees upon the growth of plants has not been given the attention and thought it deserves. In every new agricultural region of the west old timers commonly remark that the climate has changed. When they first came to the country it was impossible to grow many plants which now flourish. Apparently the meteorological records do not bear out the statement that there has been a change in climate, that the average rain-fall is more or less or that the temperature is higher or lower than for a series of years twenty years or more ago. That fruit trees or any other class of plants easily succeed now where in earlier times they generally died, is well known. These first attempts were made in exposed places where the winds and summer suns had unchecked access to their tender trunks and branches. It is true that many tender varieties were planted, but even the hardier kinds did not flourish. As the country develops, buildings and fences are constructed and that which is more important, windbreaks of hardy trees are planted which temper the winds, shade from the scorching sun, prevent rapid loss of water by evaporation and make the place habitable for plants which could not live there before. The people who came to Denver and Northern Colorado thirty years ago at first despaired of growing even hardy fruits and other crops. Now enormous quantities of fruits are raised and where sufficient shelter by surrounding hardy trees is furnished, even peaches are reaching perfection.

In Wyoming we have the same conditions, and that our young orchards have succumbed to sudden severe changes in the weather should not discourage the planter. There can be no doubt that they will eventually succeed.

The kind of plants which are useful to man have been made so by long years of cultivation and care, under conditions essentially different from ours. Therefore when planted here they must be given such care and shelter as will partially meet the conditions to which they have been accustomed. By increasing the number of hardy native trees we produce the best wind-breaks. When enough of them are growing upon every farm in a community the effect upon plants and stock is virtually the same as moving to a lower altitude or many miles to the south and the difficulties at first experienced in raising many fruits no longer exist. With these facts in mind it is readily seen that the planter of trees is a public benfactor, not only of his own time but of all time to come.

The kinds of trees to plant first are those which naturally grow under the most adverse conditions. After these become a protection more tender and desirable kinds will succeed. There are a few tree claims and wind-breaks outside of our towns, but the majority of our farmers have given the subject little attention.

The typical Wyoming ranch is everywhere thought of as a collection of low buildings, fences and hay stacks, without a tree in sight. Our picture is of such a ranch near the mouth of No Wood River in Big Horn County. This condition is rapidly changing, however. With the development of the irrigated farm these temporary ranches are being transformed into comfortable homes. In rural districts as in towns the first plantings are for shade and ornament and

A TYPICAL WYOMING RANCH.

practically all the trees other than fruits planted in Wyoming up to the present time have been set out for such purposes. In the interest of improvement and better taste we would discourage the usual methods pursued in so-called ornamental planting. Landscape gardening is the highest type of art and in its practice he who imitates nature most closely is the best artist. Nature never planted her landscapes with her most beautiful figures in rows, each row equally distant from its neighbor, the figures in the rows set at equal distances and all in mathematical exactness with regard to every feature of the scene, yet how often is this process followed out in the attempt to decorate home grounds. Were it not for the far reaching influence of such plantings in tempering the winds and climate and that trees anywhere are beautiful in contrast to the usual barrenness of the plain, I would say that it were better not to plant at all. I would not discourage rows of trees along our streets or fences, ditches, and the borders of orchards and gardens for shelter belts. Here they become a part of the general scheme, are useful, beautiful, in place. In ornamenting the home grounds let every yard be a landscape with harmonious effect, reflecting the artistic taste of the owner. A natural landscape delights us because there is variety, irregularity, and curved lines of beauty everywhere. We can only improve on such landscapes by adding variety while yet preserving harmony, and thus securing throughout a sense of order, unity and neatness. In planting yards, then, set trees and shrubs along the borders with well designed spaces to give the effect of seclusion in one part and of openness and distance in another. A small yard can be made to appear spacious by proper care exercised in the planting. Trees or objects which are grotesque or striking should never be put in prominent places as in the center or foreground of a lawn. In such localities they detract from the harmony of the whole, by suddenly attracting the attention to a single incongruous object. The entirety of the scene is marred or lost. By keeping these simple rules in mind every planter can produce effects which will be pleasing. There is the greatest opportunity for indivuality and chance to secure results which have a meaning of their own. With our somewhat limited list of trees which succeed in unsheltered places, there is consequently a necessity for careful thought and study to secure the best results in the end.

THE PLANTING AND CARE OF TREES.

So much has been written on this subject that we will only try to indicate that which seems to be the best practice for our state.

1. In taking up trees get plenty of roots. Protect the roots to keep them from drying out.

2. The more roots the better. We do not believe in root pruning.

3. A transplanted tree should be set in the ground the same depth it was when standing in the nursery or forest before it was taken up, and no deeper.

4. A hole should be dug large enough to accomodate all the roots without bending or breaking them.

5. In setting trees spread the roots naturally. Sift good soil in, around and over them, pressing it down. Then fill the whole with water. After the water has seeped away finish filling with soil, packing firmly around the trunk.

6. Moderately prune back the tops of deciduous trees. Cutting back large tree trunks when transplanting is a bad practice, as they invariably die somewhat below the cut, becoming unsightly, and from this nucleus decay is very apt to

spread, gradually creeping down the center or one side of the main trunk, deforming and sometimes eventually killing the tree. Always make slanting cuts on top limbs and cover cuts with shellac or paint.

7. The roots of evergreens should never be exposed to the air. When they dry out the resin or pitch in the bark becomes thick and water will never again thin it.

8. After the tree is set out never let it suffer for water. Cottonwoods and willows need a continual supply but will not do well if there is no drainage.

9. Never allow sod or weeds to grow immediately around the trunks of trees. If the trees are planted close together in groves or belts for wind-breaks the sod will not trouble around the bases.

10. In pruning trees cut out all dead branches. If for wind-breaks or shelter allow the lower limbs to grow. In cutting off a limb or branch never leave a stub on the tree but trim it smooth with the trunk.

11. For ornament plant trees in clumps or groves instead of rows. For shelter plant on the sides from which prevailing winds blow. In this state this will almost invariably be on the south and west. For general utility plant in every favorable place where they can be irrigated.

12. Use judgment in feeding trees and in preventing insects and disease from feeding upon them.

EXPERIMENTS AND OBSERVATIONS.

In 1892 small plats were set aside upon the Experiment Farms at Lander, Laramie, Saratoga, Sheridan, Sundance and Wheatland for experiments with shade and forest trees. In no case were the plats protected by wind-breaks or other shelter, though the farms at Sundance and at Lander were favored somewhat by being near the surrounding mountains. As few had attempted to grow trees the first object was to determine by trial what kinds would succeed in each locality. The most of the trees set out the first year were two years old, though some seedlings were used. In 1895 seeds of a number of varieties were planted. The differences of altitude with accompanying weather changes and the conditions of climate and soil have produced different results in each part of the state. At high altitudes, as upon the Laramie Plains, the growing season is comparatively short. Sudden frosts in the fall arrest the growth of many trees before they have ripened their wood. Some of the slow-growing kinds, as the hard-wood trees, fail to increase in size above the ground because each season's growth dies back to the original stem or to the top of the ground in the fall or winter. This has occurred year after year upon the ash, elm, and honey locust, and even upon the willows where given no protection or moisture through the winter. This is well illustrated in the picture of white ash and elm trees showing six years' growth at Laramie, and of willows along the ditch in foreground of the picture showing cottonwoods and willows of five years' growth at Laramie. There are two white ash at the left and a white elm at the right of the one foot rule. These trees were planted upon the Experiment Farm when seedlings and irrigated each summer. After having stood six years they were taken up and photo-

WHITE ASH AND ELM—6 YEARS' GROWTH, LARAMIE EXPERIMENT FARM.

graphed. A good root development has been made for the size of the tops but the small whip produced each summer dies down to the ground the following winter. As the altitude decreases or more protection is afforded the season's growth increases and the dying back in the winter becomes less frequent. In a protected place in Cheyenne a thousand feet lower than the Laramie Plains we have a record of a season's growth on white ash of nearly three feet while only a few of the top limbs died in the winter. At Wheatland, two thousand five hundred feet lower than Laramie, white ash made a growth in one season of fifty inches and no trouble had been reported of even the top limbs dying back.

The cause of the winter killing of trees and shrubs, as is well set forth in Bulletin No. 15 of this station by Professor Aven Nelson, is the drying out during the winter. Reasons are also given in the same bulletin for believing that such loss of moisture is greater at high altitudes.

That shelter by surrounding trees, buildings, or other objects which protected from winds, secures the same effect in saving trees through the winter as does a lower altitude with its longer growing season, is well illustrated by the fact that we have been unable to grow boxelders at all upon the Experiment Farm while in sheltered yards in Laramie the trees have attained considerable size.

The following notes indicate briefly the results of our trials with different trees, the general hardiness and utility of each and how they may be propagated or obtained.

COTTONWOODS (*Populus.*)

Five species of poplars have been found native in the state.* Three of these are commonly called Cottonwoods, one the Balm of Gilead and the other the Quaking Asp.

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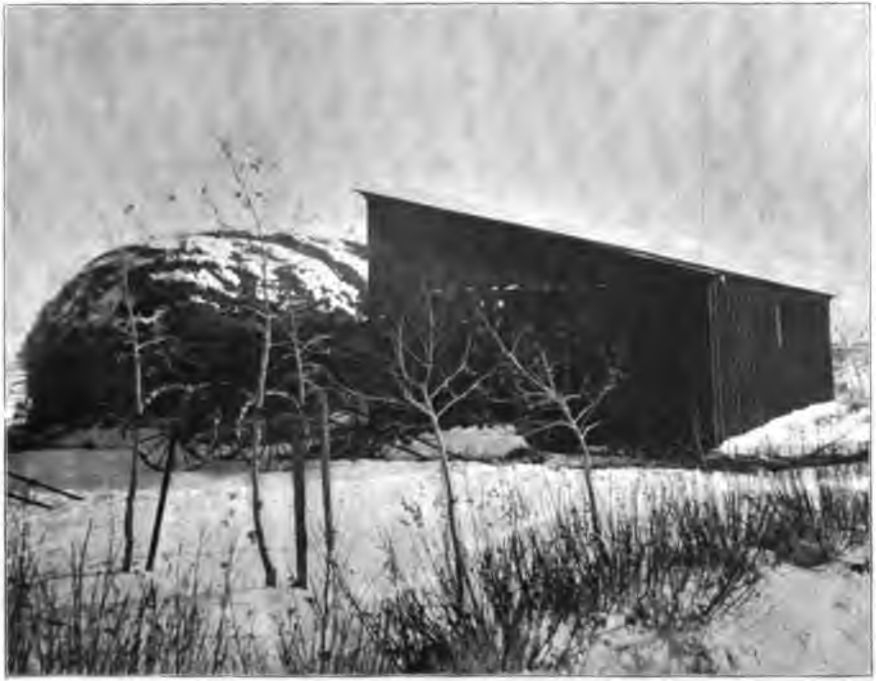
*See Bulletin No. 28, p. 180.

The poplars are diœcious, i. e., the male and female flowers are borne on separate trees. As the cotton is such a nuisance in yards and along the streets it is quite important only to plant in such places the male trees, which produce no cotton. We know of no way of telling the trees which produce cotton from those which do not when they are young, but it is an easy matter to propagate the kind wanted. Cottonwoods grow readily from cuttings. Cuttings from male trees or those which do not bear cotton will produce male trees. Anyone raising their own trees from cuttings should bear this in mind, in order to get rid of this objectionable feature. Some trouble has been experienced in this state by such rapid growing trees becoming bark-bound, especially on the south and west sides. When this occurs, split the bark open up and down the trunk once or twice during the season. Cottonwoods will grow in most trying situations if given plenty of water. They have succeeded better with us where planted upon rather shallow soil with sandy or gravelly subsoil and given a continual supply of water. In regard to their general usefulness, Professor Bailey of Cornell, writing for New York State, says: "As a group, the poplars possess comparatively small value in landscape planting. * * * A very rapid growing tree nearly always produces cheap effects. * * * There is little that suggests strength and stability in willows and poplars and for this reason they should always be used as minor or secondary features in ornamental or home grounds. Where quick results are desired there is nothing better to plant than these trees,but better trees, like maples,oaks,or elms,should be planted with them and the poplars and willows should be removed as fast as the other species begin to afford protection. * * * The cottonwood is perhaps the best of all, spreading its gray branches far and wide, but like the aspen, it is cheerful and restive. One is not moved to lie under it as he is under a maple or oak. Its leaves rustle with the



BROADLEAF COTTONWOODS AND WILLOWS—5 YEARS' GROWTH, WITHOUT SHELTER, LARAMIE EXPERIMENT FARM.

slightest movement of air. The ripple of its foliage always recalls to my mind the play of wavelets upon a pebbly shore. The day is never so dark but the cottonwood reflects a flood of light."

Force of circumstances necessitate our disagreeing with a part of these remarks, for we would be loath, indeed, to discard the cottonwood for our permanent plantings. The number of kinds of trees which we know to be hardy enough to stand our climate is limited. In fact, the only one which is of any great use for shade at the altitude of a great part of the state is the cottonwood. We admit that their constantly moving foliage is not conducive to the midday siesta, but on the other hand they are emblematic of the nervous energy, the bustle, the push characteristic of western people. Once for all we might as well decide to accept the cottonwood with thankfulness that we have so noble a tree and set about conscientiously to make the best use possible of it in producing pleasing effects in our landscapes.

RYDBERG'S COTTONWOOD OR SMOOTH BARK.

(*Populus acuminata* Rydberg.)

This is the hardiest and best of our native cottonwoods for cutlivation in this state. It will grow anywhere if sufficient moisture is supplied, and thrives especially well where a number are planted together, as they shelter one another. On account of its hardiness, rapid growth, and habit of assuming a good shape, there is nothing to equal it for general planting under adverse conditions, or for a first shelter to protect more tender species. It is especially useful for wind-breaks, for planting along our streets, and single specimens standing near the border of a yard are beautiful. Some specimens planted upon the Experiment Farm at Laramie have succeeded well, making several times as much growth as the broad leaved cottonwood.

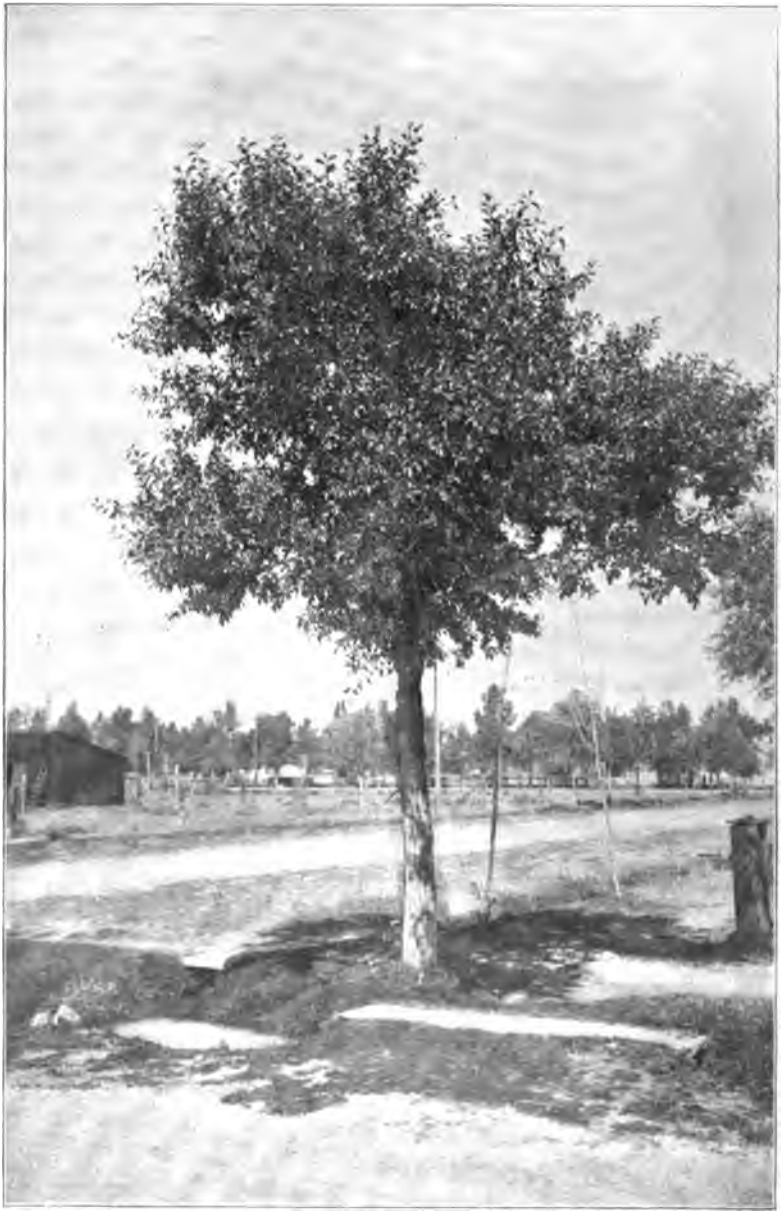
At an altitude of over 7,000 feet trees one inch in diameter will become five to seven inches in diameter in five years. Every ranchman in the state who can irrigate them should plant shelter belts and wind-breaks of this species and should have them in his yard for shade. Cottonwoods are greedy feeders and other trees or plants do not do well when planted too close to them, but their good influence will repay the amount of room required. This tree, as is true of all our native poplars, produces good fuel but is of little or no value for lumber.

BROAD LEAF COTTONWOOD OR CAROLINA POPLAR.

(*Populus deltoides* Marsh, or *P. monolifera* Aiton.)

This tree is common at Wheatland and in the northwestern portion of the state. Around the first artificial lakes or reservoirs at Wheatland thickets of these trees came up from seeds which made their way down the ditches with the irrigation water. It is much used as a shade tree. There are some excellent specimens in Laramie. Seedlings set upon the Experiment Farm in 1893 subject to the exposure of the open plains have lived, though the growth has been comparatively slow. They have attained a height of eight to ten feet and a diameter of two or three inches. They have undoubtedly been dwarfed somewhat by injury from plant lice which were found in great numbers on the leaves in 1896 and 1897. Prevailing southwest winds have caused them to lean in the opposite direction. A few specimens are shown in the illustration of this variety, at Laramie. Others on the plat were removed to make room for the shed and stack shown in the cut.

At Wheatland small trees set out upon the Experiment Farm in 1892 became four inches in diameter and twelve to fifteen feet high in three years. This species is not so desirable for general planting especially at high altitudes as is the smooth bark or Rydberg's Cottonwood.



NATIVE BALM OF GILEAD, LARAMIE

NARROW LEAF COTTONWOOD OR BLACK COTTONWOOD.

(*Populus angustifolia* James.)

This is one of the most common native species, often growing to great size. It is hardy but at high altitudes is apt to become scrubby and unsightly where not well cared for and systematically pruned. Many of these trees have been planted in towns and some are making a good appearance. Some of the finest trees in Laramie are of this species. It does not grow so rapidly as the smooth bark, but when large its great spreading tops make it as effective a tree. Ordinarily it is not so highly prized as either the smooth bark or broad leaf given above.

BALM OF GILEAD. (*Populus balsamifera* Linn.)

Apparently this tree is not abundant in the state. There is considerable variation in the shape and size of the leaves but they can be usually distinguished by the resinous or sticky buds. This tree is long lived and hardy, succeeding well almost everywhere, although the broader leaved varieties have been more or less tender in Laramie. Professor Bailey states that their tops are hardly broad enough for the best shade but are good to plant among other trees. The sticky buds and leaves collect too much dust and dirt to make them desirable in cities where there is much smoke. Our illustration made from a protograph of one of these trees in Laramie shows a broader head than is generally formed by this species. Balm of Gileads are reported as not doing well upon the Lander Farm as they require so much water that other things are injured by it.

QUAKING ASP OR ASPEN. (*Populus tremuloides* Michx.)

Many of these trees have been transplanted but I have yet to see one in cultivation which I consider a fine specimen. Those which have been transplanted do not seem to grow well, probably because they do not receive sufficient moisture through the winter. They are pretty trees, throwing out their catkins before others have started in the spring, bearing through the summer their gay foliage which is never still, and at the first heavy frost in the fall turning to bright yellow and gold. They are useful for planting in yards with other trees as single or scattered specimens and are more esteemed than the cottonwood for setting out in young evergreen plantations to shade and protect the trees.

HORTICULTURAL VARIETIES OF POPLARS.

There are a large number of varieties of poplars in cultivation, other than those which are native to this state. I only know of one of these which has been introduced here. This is the Lombardy Poplar, specimens of which have been noticed in several places. It is a short-lived tree, however, and probably will not be planted to any extent. Such striking growths are too often abused by being used indiscriminately where they produce unpleasant effects in the landscape We have little regret that the Lombardy does not succeed well here as is it of so little value for shade, ornament, wood or timber. The so-called silver poplars which have been planted here are silver maples, spoken of under maples, rather than true silver poplars. A number of Russian Poplars have been introduced which would, no doubt, prove of value for planting in this state but as yet they have not been tried*.

WILLOWS. (*Salix.*)

The willow is fully as hardy as the cottonwood but is not as useful for all kinds of planting. They are easily propagated by cuttings but they require a large amount and a

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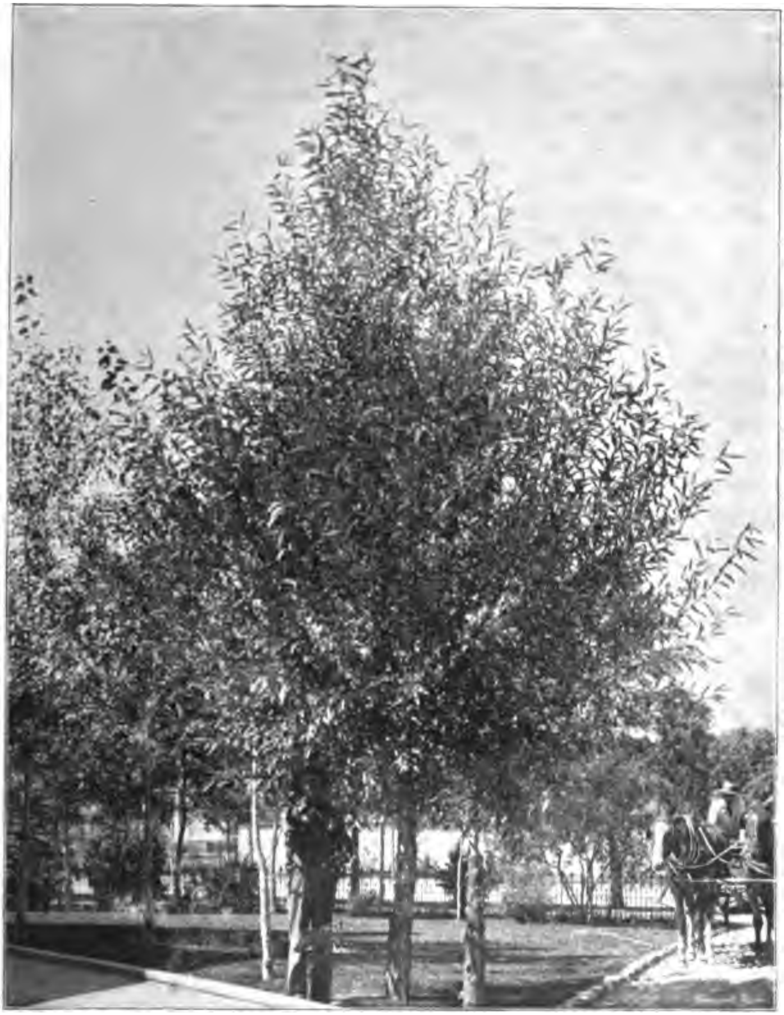
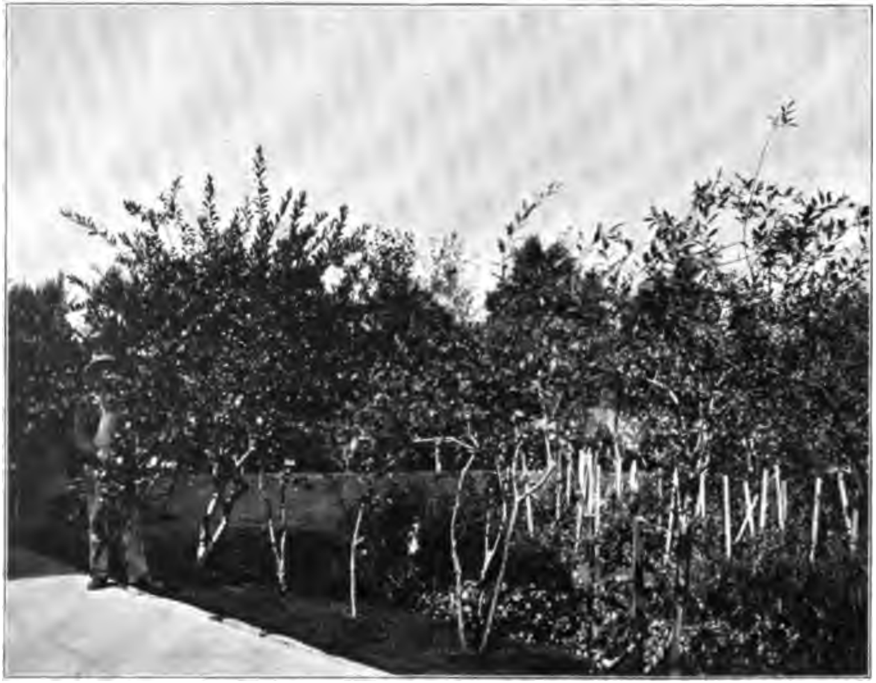
*Anyone interested in these poplars should obtain Bulletin No. 9 of the Minnesota Experiment Station, St. Anthony Park, Minn. and Bulletin No. 68 of the Cornell Station, Ithaca, N. Y.



RUSSIAN (WHITE) WILLOW IN YARD OF EDWARD IVINSON, LARAMIE.



SCREEN OF NATIVE WILLOWS ON GROUNDS OF EDWARD IVINSON, LARAMIE.

continual supply of water. Some of our native willows grow to a large size but they do not produce a shapely tree. They are easy to cultivate, however, and may be used to advantage in many places. Our illustration of a screen of native willows represents their usefulness for this purpose. These willows grew from cuttings in three years. In this case they are used to separate the garden from the house and front lawn.

A so-called Russian willow* has been grown upon the Experiment Farms at Laramie and Lander. Upon the Laramie Farm they have died down to the ground nearly every winter. A few specimens which had more moisture have attained a larger growth, but, as a rule, they only produce a fringe of whips along the ditches, as shown in the illustration of cottonwoods and willows upon the Laramie Farm. Larger trees of the same species have succeeded well upon the University Campus and Mr. L. Fee has experienced little difficulty in raising effectual wind-breaks of them upon the river bottom.

If kept properly trimmed they form a shapely tree in a short time. We show a picture of one of these trees on the grounds of Mr. Ivinson as it appears three years after transplanting. At Lander they produced a fairly good wind-break in three years, having reached a height of twelve to fifteen feet. The larger ones now have diameters of from two to four inches.

Osier willows brought from Nebraska have succeeded well upon the Laramie Plains. Upon the ranch of Mr. James King, seventeen miles from Laramie, they have made large growths, producing an effective wind-break for his garden. A specimen upon the Experiment Farm which stands near the main lateral where it gets plenty of moisture has grown well and shows no tendency to winter kill.

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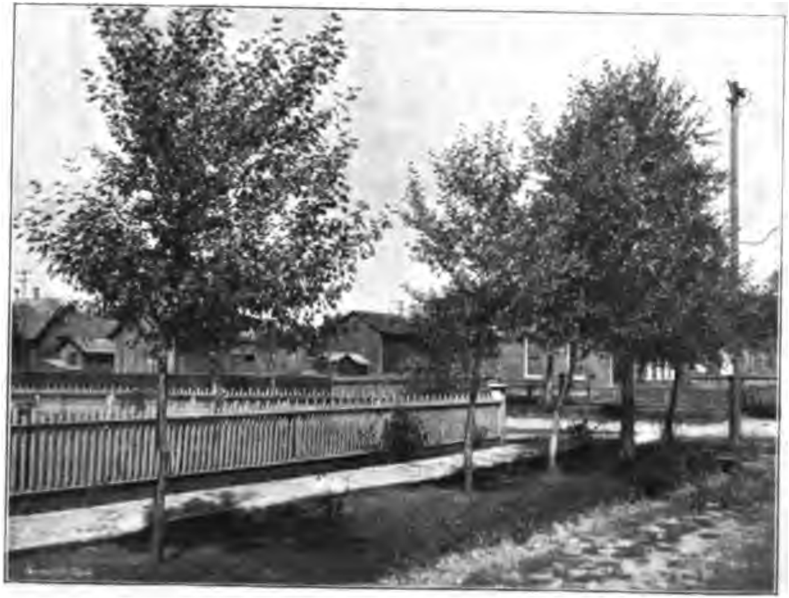
*Our botanist, Prof. Nelson, sent specimens to Prof. Bebb, a few years ago, who stated that this was the white willow crossed with another species.

MAPLES. (*Acer.*)

So far as we are informed the hard or sugar maple has not been tried other than a few seeds planted on the Station Farms, which failed to grow. Soft maples will succeed in sheltered places below five thousand feet altitude. Those planted at Laramie have failed. Three species are native in the state, the small bush maple, common in mountain ravines; the boxelder, along nearly all our streams at low attitudes, and our botanist has found a species, the Utah maple, on Bear River near Evanston. The following species deserve special mention:

Boxelder (*Acer negundo* Linn.)—Boxelders are too tender above 7,000 feet altitude except in the most sheltered locations. They may be sparingly used in yards, where they often produce handsome trees. Seeds planted on the Experiment Farms have not succeeded very well except at Lander, where seeds planted in 1895 have produced trees two inches in diameter and twelve feet high. They are subject to attacks of the boxelder leaf roller which must be kept in check by spraying or the trees become a nuisance as long as they live and are eventually killed by these insects. (For remedy see Insect Pests.)

Silver Maple (*Acer saccharinum* Linn.)—This species is often planted in our towns under the false name of Silver Poplar. It is hardy but shows a tendency to die back in the winter at Laramie. It has a disagreeable habit of suckering from the roots, and if neglected soon forms an unsightly bramble of underbrush. Single specimens, well cared for, in the back yard, may be tolerated, but they are too gay and striking for good effects in front yards or along the street. Our illustration shows some fair specimens planted along a street in Laramie.



SILVER POPLAR (MAPLE), LARAMIE.

LOCUST. (*Robinia.*)

Honey Locust planted on the south side of the University campus lived four or five years, but did not increase in size, as the small growth made each summer died back to the main stem the following winter. At Lander a good stand of both Honey and Black Locust was secured from seed, but reports from there state that they are killed back each winter. In a yard in Laramie there are good specimens of Black and Yellow Locusts, but they have not been grown long enough to determine whether they can be made to live through the winter or not. Fine specimens of these trees have been observed in Cheyenne. They will undoubtedly succeed in Wheatland and at other places along the eastern border of the state.

CATALPA.

This species has not succeeded upon the Experiment Farms. It can probably be made to grow in sheltered places at low altitudes.

MULBERRY. (*Morus.*)

The Russian Mulberry tried upon the Experiment Farms has been killed during the winters. We have seen fine thrifty trees full of ripe fruit at nearly seven thousand feet altitude upon the ranch of Mr. Keach located in a protected valley in the mountains about twenty-five miles south of the Wyoming line. With proper protection they will undoubtedly succeed in parts of the state.

GREEN ASH. (*Fraxinus lanceolata* Brokh.)

The Green Ash is found native along streams in the northern part of the state, having been observed as far south as the Canon of the North Platte above Orin Junction. It will undoubtedly succeed where properly cultivated in that region.

WHITE ASH. (*Fraxinus americana* Linn.)

The investigations by the station show that the White Ash needs a longer season than we have at altitudes above six thousand feet. The illustration of White Ash and Elms grown from seedlings at Laramie show the small growth made in unsheltered places. Larger trees set out upon the Experiment Farm and the University Campus lived through the first winter but made very small growth. In Cheyenne, at six thousand feet altitude, there are some thrifty, well-shaped ash trees. In the railroad park near the depot they made a growth this season of from one to three feet. A good many White Ash were set out around the Capitol grounds. The State Engineer tells me he has concluded that the season is too short for them.

At Lander, Sundance and Wheatland they have succeeded well. At Lander they made a growth of over three feet in the season of 1895, but the heavy freeze on September 22nd of that year cut them back. Since that time they have made new growth and Mrs. Meyer reports now that they are two inches in diameter and nine feet high. We have no report on the White Ash from Wheatland since 1895, but at that time trees which were set out when one year old in 1892 had made a growth of six to ten feet high and about one and one-half inches in diameter. Our illustration of White Ash trees at Wheatland shows a growth of four feet two inches in 1895.

WHITE ELM. (*Ulmus americana* Linn.)

The larger trees of White Elms planted at Laramie died the first season. Seedlings set out in 1892 have lived but have made such small growth (see illustration) that they are difficult to see in the plat. They seem hardy at Wheatland where in three years they reached a diameter of two and one half inches and attained heights of ten to twelve feet. At Lander they have died back each winter. In nearly all

WHITE ASH TREE. Wheatland, 1895. Season's Growth, 4 ft., 2 in.
(Cut loaned by Hon. J. M. Carey.)

parts of the state they will require good shelter in order to succeed.

BUTTERNUTS AND BLACK WALNUTS. (*Juglans.*)

At Wheatland and at Lander Butternuts and Black Walnuts have lived but have only made small scrubby growths. In 1895, at the former place, they made a season's growth of two feet. Black Walnuts are more hardy than Butternuts at Wheatland. Trees set out at Lander in 1892 are now about two inches in diameter at the ground and four feet high. They require a low altitude and the best of shelter from the wind and sun.

MOUNTAIN ASH. (*Pyrus americana* Marsh.)

This is a very ornamental little tree where it can be made to thrive. It is native to the state in ravines in the mountains above 8,000 feet. A dozen were set out at Laramie but we failed to make any of them live. They require a sheltered locality and plenty of snow or other moisture during the winter. In Cheyenne there are a few beautiful specimens.

BIRCH. (*Betula.*)

There is a native species in the Black Hills of Crook County. We have not attempted to grow them upon the Experiment Farm but believe them worthy of careful trial for ornamental planting.

FRUIT TREES FOR ORNAMENT.

Those fruit trees which succeed with us are of little value for shade. However, they can often be used to advantage associated with other trees in ornamental planting and their usefulness makes them doubly desirable. Some of the apples, as the Wealthy and the Siberian Crabs, are almost as hardy as cottonwoods and willows. They may be

GROVE OF DOUGLAS SPRUCE ON UNIVERSITY CAMPUS, LARAMIE.

lots in town many have succeeded better than we. The following varieties merit special mention:

Silver or Blue Spruce (*Picea pungens* Englm.)—This is a rapid growing tree and the most beautiful of our evergreens. It is a native, growing along streams or in wet swampy places in the mountains. On account of its natural habitat it is the only evergreen which grows well upon our lawns where so much water is used. When small it closely resembles the Engelmann Spruce but the latter grows on high ground. Nurserymen claim to have little difficulty in growing Silver Spruce but our experience indicates that they can hardly be made to succeed where no protection from winds and sun is given. Out of dozens of them set out without protection we have succeeded in establishing a single tree so we know it is growing. A number recently set out seem to be growing well. There are many fine specimens in the yards and parks in Cheyenne and Laramie. Mr. Thessen, who was caring for the railroad park in Cheyenne this summer, states that he has not lost a single tree. The grass is not allowed to grow around the bottom of the tree trunks and when watering the lawn the tops of the spruce trees are sprayed every day. As our frontispiece we show an illustratoin of a very good specimen in the yard of Mr. Edward Ivinson in Laramie. This tree was transplanted to its present position about ten years ago when it was quite small.

Douglas Spruce (*Pseudotsuga taxifolia* (Poir) Britton.)—This is a common tree in our mountains which is sometimes transplanted with the thought that it is the Silver Spruce. They are easily told apart, however. It stands transplanting fairly well if carefully done but will not thrive where there is as much water as is required by the Silver Spruce. There are some fairly good specimens in yards in Laramie. Our picture shows a small grove of Douglas Spruce which has been set out on the University Campus the past two seasons. This picture represents the manner in which we think the trees are more apt to grow by protecting one another and catching the winter snows and illustrates the correct method of producing artistic landscape effects.

Cedars (*Juniperus.*)—Cedars do not seem to have taken kindly to transplanting in Laramie. There are some nice specimens in yards in Cheyenne. Single specimens are very ornamental, especially if properly backed by other trees so they form a part of the whole effect. The cultivated variety should be obtained from some reliable nurseryman.

ARTIFICIAL ROOT PRESSURE.

The artificial application of root pressure in horticulture is new. It has been introduced by Professor E, S. Goff of the Wisconsin Station. He gives a detailed account of experiments carried on along this line in the Fourteenth Annual Report of that Station. Professor Goff attributes the failure to start growth promptly after trees have been transplanted to the lack of sap pressure in the cells. Under normal conditions this pressure is supplied by the action of root hairs. These, of course, are destroyed in the process of transplanting. New root hairs must be produced before the plant can re-establish this sap pressure. During the time that the tree is taking up so little moisture from the soil it is continually losing a large amount by evaporation which naturally lowers its vitality and ability to make quick, rapid growth. It seems plausible, therefore, that artificially keeping up the pressure in the tree, supplying water to take the place of that lost by evaporation and continuing the natural conditions so it can perform vegetative functions would insure the life of the tree and accelerate its growth. Professor Goff has demonstrated the value of his method with newly planted apple trees. We have tried the method upon fruit trees at Laramie and, while our experiments were not conclusive. it seemed very beneficial. Our object in presenting the matter in this bulletin is to interest those who are planting trees of any kind, with the hope that they will cooperate with this station in order to make the experiments sufficiently extensive to determine what value attaches to it.

The method is so simple, inexpensive and easily applied that anyone can use it and if it proves effectual in preventing the death of even a small percent of transplanted trees it would pay for itself many times over. When the trees are planted a receptacle holding distilled or rain water is placed at the height of, or a little above, the top limbs and connected to one of the roots of the tree by a tube and small piece of rubber hose. Bottles and glass tubing or a metal dish at the top of a piece of gas pipe may be used. It is not claimed that attaching this apparatus will do any good except during the time new root hairs are being formed, the roots are establishing themselves and the new leaves are starting. It is only needed a few weeks at the most and the materials used can be utilized for other trees. Anyone who will co-operate with the station in making tests upon newly planted trees will confer a favor by corresponding with the Director. We only care to experiment with it upon spring planted trees, but sould like to make careful tests upon any kinds of trees, whether deciduous or evergreen and in different parts of the state.

INSECT ENEMIES.

Only a few insects which produce any alarming injury to our trees have been observed. There are a few, however, which demand immediate attention and energetic action in order to prevent the destruction of our hardiest varieties. It is not our purpose here to write a scientific treaties upon this class of insects, but to call attention to the danger from certain pests and give as briefly as possible remedies for their destruction.

PLANT LICE.

These are the most injurious insects in the state. They are especially destructive to cottonwoods and have been very injurious to willows and spruce These wonderful little insects are known to everyone as plant lice or as "green" or brown flies. They are so small that even when they occur in great numbers they are easily overlooked and though they fatally damage the trees the work is done so unobtrusively and slowly that they are too often ignored. There are a good many genera and species of plant lice but it will not be necessary to describe or classify them here. Two species working on the cottonwood are named in Bulletin No. 2 of this station.*

"The two species of lice in this locality on the cottonwood are *Pemphigus populimonilis* ? Riley, and *Chaitophorus viminalis* ? The former is less numerous than the latter. The first-named species attacks the leaf near its margin. By the continual puncturing and irritation to the leaf the growth is retarded at this point. The growth on the opposite side of the leaf is so rapid that within a short time a pocket-like cavity is formed, in which the lice live. The other species differs in its habit from its relative. Instead of forming a gall or protective covering for themselves, they congregate upon both sides of the leaf near the midrib and by their continual puncturing soon cause the foliage to curl, become brown and finally drop from the tree." Undoubtedly there are other species working upon the cottonwoods and willows. We have not observed that early dropping of the leaves generally follows the attacks of our common species. I have also found undoubted evidence of work upon the roots by one or more other species.

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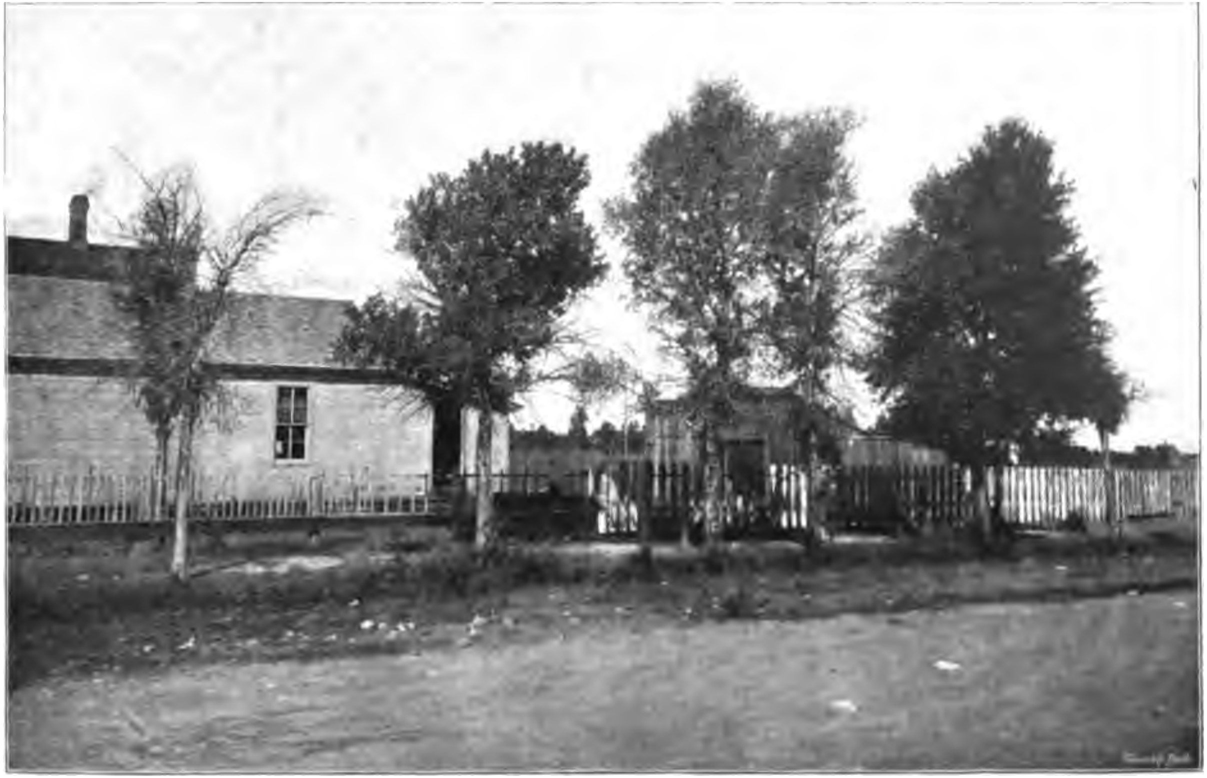
*This bulletin which was written by F. J Niswander, then with the Station, has been exhausted. As it can no longer be supplied I have quoted in full the section on species and a little further along the one on remedies.

Plant lice may or may not produce galls either upon the leaves or roots, depending upon the species. Where there are attacks upon both the leaves and roots more serious injury is done in a short time. They are so destructive to the cottonwoods in Laramie that unless some change in natural conditions, as unfavorable seasons or the increase of their enemies, destroys them or unless the people take the matter in hand, we predict that in ten years' time there will be very few trees left. The trees gradually become weak, but they may not show the bad effects until time of throwing out the leaves in the spring. The foliage comes out late and the leaves have a small, yellow, sickly appearance. After struggling along after this manner for one or more years, the entire tree dies. Where neglected by not being prunned or supplied with sufficient water they die more quickly. Our illustration shows trees on a street in Laramie which are being destroyed in this way The one to the left in front is entirely dead The one back of it, inside the fence, and the three to the right are so out of health that they will probably not come into leaf another year, while the large, green tree at the right shows little effect as yet and may live several years. The trees in this picture are typical of the condition of a great many cottonwoods in Laramie and every tree owner shold do something at once to prevent further destruction. These insects live by sucking the juices of the plant upon which they feed. They ordinarily collect in great numbers on the under side of the leaves or upon the roots under ground. Upon their backs, near the rear end of the body, they bear a pair of siphuncles or honey tubes, through which is secreted a sweet liquid known as honey dew. This liquid becomes sticky and where the lice are numerous often covers the leaf, helping along the destruction of the tree by choking it to death. Sometimes so much honey dew is excreted that it falls like rain, and walks under the trees are covered with it.

Ants are the friends of plant lice, attending them regularly to feed upon the honey dew and caring for them or their eggs through the winter. It has been proven that at least some species cannot live unless they are taken care of by ants. If this is true of the species affecting our cottonwoods, and it seems likely, destroying the ants is a good remedy. Mr. Ivinson informs me that they have destroyed the ants wherever they have been found on his grounds, by pouring boiling water into their nests, and that his trees have not been bothered by lice. So far as I have observed, they are the only trees in town which do not show injury from these insects. For destroying ants, there is probably nothing better than bisulphide of carbon. Pour two or three tablespoonfuls into each hole and press the soil around and over it with the foot. This will usually kill everything in the nest.

There are several kinds of plant lice which live on our evergreens. They are often numerous on the Douglas Spruce, and one species (*Chermes abietis* Linn.) produces small, brown, cone-shaped galls at the ends of the limbs of the silver spruce.



COTTONWOODS IN LARAMIE, SHOWING EFFECT OF PLANT LICE AND NEGLECT.

REMEDIES.—Professor Gillette of the Colorado Station recommends collecting and destroying the galls on the spruce during the last half of June or early in July and to apply kerosene emulsion during the latter part of May. He also states that kerosene emulsion is effectual in killing the lice on Douglas Spruce.

When there are lice on the roots of trees they may be destroyed by working from three to six pounds of tobacco dust or a good quantity of the stems into the soil around the base of the tree and then thoroughly wetting it. The water takes enough nicotine from the tobocco down around the roots to destroy the lice. Professor Smith, in his book on "Economic Entomology" (P. 131), says salty liquids will kill plant lice, and recommends the use of potash fertilizers around the trees. Bisulphide of carbon injected into the ground is sometimes used and is effectual in killing the insects, but it is more expensive than tobacco and, using too much, is apt to injure the tree. It is necessary to destroy insects which feed, as do the plant lice, by applying poisons which kill by coming in contact with their bodies. All that I need to say regarding remedies for the lice on the parts above ground and how to prepare and apply them is contained in the following quotation from F. J. Niswander, in Wyoming Bulletin No. 2: "Various remedies have been suggested for the destruction of plant lice, but none seems to be more effective than an emulsion of kerosene oil and soap. This emulsion is made as follows: 'Dissolve in two quarts of soft water one-fourth pound of hard soap by heating to the boiling point, then add one pint of kerosene oil and stir vigorously for from three to five minutes.'—(Cook). The best way to do the stirring is to pump the mixture from one vessel into another or back into itself with the force pump. This will form a thick, creamy mass that may be diluted to any desired strength. To the mixture just formed we then add ten pints of water. This is the usual strength, although the emulsion will kill the lice if twelve pints of water are added. It is better to add the larger amount of water, as there is some damage done the foliage when only ten pints are added. The emulsion should always be applied with a force pump. Another excellent remedy for plant lice is Buhach or Pyrethrum. This is the yellow insect powder sold in the shops for the destruction of insects. If two tablespoonfuls of this be thoroughly stirred in a large pail full of water and sprayed upon the trees excellent results will follow the application. Too much care cannot be taken to make a thorough application, otherwise it will do no good.

"In the application of insecticides there is nothing that will insure success like thoroughness. A dashing spray, one that will reach every leaf upon all portions of the tree, is one of the essentials of a good force pump. There are many pumps upon the market and all have certain features that are commendable."

BOXELDER LEAF ROLLERS.

(*Cacœcia semiferana* Walk.)

This insect proves very destructive, at times practically defoliating the boxelders, leaving them unsightly and in such condition that they are slow to recover. It is popularly thought to be the same as the leaf roller of fruit trees. In Bulletin No. 47 of the Colorado Station, Professor C. P. Gillette, in speaking of it, says: "This insect is a close relative of the Fruit Tree Leaf Roller and it is quite commonly thought not to be different It seems to confine its attacks exclusively to the boxelder, however, in this state, as I have never yet found the larvae feeding upon anything else. Its habits and appearance are much like the fruit tree species."

REMEDIES.—As the larvae are external feeders, eating the whole leaf, they may be destroyed with any of the stomach poisons. Spray with Paris Green mixed with water at the rate of one pound of Paris Green to 150 to 200 gallons of water, keeping it well stirred. Apply when the young larvae first appear upon the leaves and again a week or ten days later.

BOXELDER BUG—(*Leptocoris trivittatus* Say.)

This insect is common all over the state. It is a flat bug about one half inch long, black, with red margins on the thorax and wings. They may often be seen walking around slowly in the fall or winter time, or collected in great numbers here and there. The young bugs feed upon the boxelder.

REMEDIES.—Professor Gillette says that the old bugs seem proof against most applications used for such insects, but that kerosene emulsion will probably kill the young bugs. He recommends killing them with boiling water when large numbers of them are found collected in one place.

ATTACUS MOTH—(*Attacus columbia* Smith.)

A large, green caterpillar, almost the size of a cigar, when full grown. covered with knobs, with yellow and blue markings, is becoming a common pest upon the willows, currants and gooseberries at Laramie. They are enormous eaters, requiring a great many leaves at a meal, and have a habit of only resting a short time between meals, so entire branches may be defoliated in a single day. The larvae spin dark cocoons of silk and produce the largest moth found in our state, the wings expanding three and one-half to four inches.

REMEDY.—Where numerous, they should be destroyed with the same spray of Paris Green as that given for Boxelder Leaf Roller.*

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*A number of caterpillars have been found eating the willows. Wherever they feed in such numbers as to be at all injurious they should be destroyed with the Paris Green spray which effectually kills any insect which feeds by eating a part or all of the leaf.

TENT CATERPILLAR—(*Clisiocampa fragilis?*)

Specimens of tent caterpillar eggs have been sent me from Natrona and Crook Counties. The eggs are laid in bundles around the stem. The larvae feed upon the apple, spinning unsightly tents in the top limbs, and become very destructive where allowed to become numerous and continue their ravages unmolested.

REMEDIES.—The egg masses must be cut off in the winter and burned. If any escape observation, the young can be destroyed by cutting off and burning the tents, or by spraying with Paris Green. Where the trees are sprayed with Paris Green for the codlin moth the tent caterpillar is usually destroyed as well.

COTTONWOOD BORER—(*Prionoxistus robiniæ* Peck.)

Injury from this insect is occasionally met with in cottonwoods in this state. They are apt to bore into the tree where there is a scar. The castings of the borers are pushed out to the surface and the sap runs out, making a bleeding place on the tree, which helps to rot the wood. The larvae become about two inches long.

REMEDIES.—As given by Professor Gillette, the remedies are to destroy the larvae by using a wire or to prevent his coming out as the adult moth by plugging up the hole or tacking a screen over it. It is difficult to destroy wood borers because they are so inaccessible.

SUMMARY.

Fifty million acres in Wyoming are treeless. About two million acres are now under ditch and large tree plantings are needed on every farm.

The influence of trees makes it possible to grow fruits and other plants which would not otherwise succeed. Shelter belts are invaluable protection to live stock. Without trees our landscape and homes are monotonous and unattractive.

As a people we should give more thought to the planting, care and pruning of our trees.

Our best trees for wind-breaks, shelter belts and street planting are cottonwoods and willows. Our most rapid growing cottonwood is the smooth bark or Rydburg's. Next in value are the broad leaf, black or narrow leaf cottonwood and Balm of Gilead.

The cause of the winter killing of our trees is believed to be their drying out during the fall, winter and spring. The remedy indicated is fall and winter irrigation, protection from wind and sun, catching the snow and any method to prevent evaporation, as mulching the ground and wrapping the trees.

The following list gives the trees which have been tried in the state for ornamental or other planting, arranged so far as we are able to do so, in the order of their hardiness, the most hardy being named first: Cottonwood, Willow, Silver Spruce, Douglas Spruce, Boxelder, Hardy Apples, Dwarf Cherry, Silver Maple, Cedar, White Ash, Green Ash, Locust, Elm, Morello Cherries, Plums, Mountain Ash, Soft Maple, Black Walnut, Butternut, Birch, Mulberry, Catalpa.

Our cottonwoods and boxelders have been more injured by insects than other trees.

The insects doing greatest injury to trees in this state are plant lice, the boxelder leaf roller and tent and other caterpillars.

For insects which feed by sucking the juices of plants, as plant lice, spray with kerosene emulsion. Those feeding upon the roots may be destroyed with tobacco and bisulphide of carbon. For those which feed upon the leaves, use a spray of Paris Green. For ants, use bisulphide of carbon or hot water.

UNIVERSITY OF WYOMING.

Agricultural College Department.

WYOMING EXPERIMENT STATION,

LARAMIE, WYOMING.

BULLETIN NO. 39.

DECEMBER, 1898.

ALKALI STUDIES, II.

BY E. E. SLOSSON AND B. C. BUFFUM.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyo.

Wyoming Agricultural Experiment Station.

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Alkali Investigations.

E. E. SLOSSON.

THE CHARACTER OF WYOMING ALKALI.

The Experiment Stations are supported for the purpose of scientific research in the problems of agriculture and they are located in different states in order that each station may study, at close range, the conditions of the region that surrounds it. From its location the chief problem of the Wyoming Station has been given to it by nature, the study of aridity, and as fast as possible the work of the Station has been concentrated on this subject.[*]

The chief difficulties in the way of agriculture in the arid region are two, the insufficient supply of water and the accumulation of soluble salts, known as alkali. The second of the these is a consequence of the first. Where watering is done by rain, pure water is added to the soil and drained off underneath, carrying with it the soluble salts of the soil. In irrigation, water containing salts is added to the soil and pure water evaporated from the surface. It was shown in Bulletin No. 24 that half a ton of alkali was added to each acre of the Sheridan Farm every year by irrigation and the land became completely useless until it was drained.

Samples of alkali from all parts of the State have been analyzed and the complete analysis will be published in the next annual report. It will be sufficient to give here the general result. Almost all the alkali of the State consists of three salts in varying proportions, sodium sulphate (Glauber's salt), magnesium sulphate (Epsom salt) and sodium chloride (common salt). The "black alkali," sodium carbonate, is fortunately very rare as it is much more injurious than the other salts. Analysis of the soils of the State shows that the percent of soluble salts or alkali is usually small, often extremely so, and it is only its accumulation at the surface that causes damage. On the other hand the small amount of water in the soil makes the alkali more injurious than if more diluted, for it must be remembered that it is not the total quantity of alkali in the soil but the strength of the alkali solution that is of importance. For example, if the soil contains 10% of water about 3% of common salt is required to form a saturated solution, but if there is only 5% of water half that amount of salt will produce the same effect and any larger amount is no worse. On unirrigated land the water content is mostly between these limits. (Bulletin No. 35.)

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[*] For a summary of the publications of the Station on this subject, see Eighth Annual Report, 1898, pages 15-50.

In many parts of the state the alkali salts are not mixed together and distributed through the soil, but are collected in large beds of single salts often very pure. Near Laramie there are beds of sodium sulphate, near Rock Creek of magnesium sulphate and near Green River of sodium carbonate (sal soda) of many acres in extent and several feet in thickness. Many theories have been advanced as to the origin of these "alkali lakes," mostly based on the assumption that they must have been made from the decomposition of rocks containing the same salts. Since there are no rocks in the vicinity whose products of decomposition at all resemble the alkali, the advocates of this theory have been obliged to construct hypothetical rocks for the purpose. If, however, we remember that the salts deposited from solution depend on the proportions, temperature and concentration, and need not be at all the same as the salts dissolved, we can account for the alkali beds without taking into consideration the origin of the salts. It is enough for us to know that all the spring and river waters of the state contain the necessary elements and the problem is merely to separate them into the forms that are actually found.

The salts in the alkali lakes can not be regarded as of any certain composition. They become liquid, that is dissolve in their water of crystallization on a warm day or are dissolved by the addition of rain water and when deposited by cooling or evaporation it would be very improbable that the same forms should reappear in the original proportion. Then too the addition of drainage water containing more salts must change the equilibrium and cause a rearrangement to form new salts. This may account in part for the widely variant analyses that have been published, and observations at different seasons of the year show startling changes. Sometimes the lake is fluid, at others solid. Sometimes it is a bed of large clear crystals of sodium sulphate decahydrate; sometimes the white anhydrous sodium sulphate covers the surface. The phenomena can be watched very prettily by dissolving the salts in a beaker of water in such proportions and concentrations as to be in unstable equilibrium. If the temperature of the room varies considerably the form, size and composition of the crystals will often be very different.

The salts contained in natural alkali are remarkable for the number of their phases. We have in the natural waters of the State from which the alkali is deposited, the bases sodium, calcium and magnesium, and the acids carbonic, sulphuric and hydrochloric. There are also sometimes present the bases potassium, aluminum, iron and lithium, and the acids nitric, boric, silicic, phosphoric and reduced sulphuric acids, but only in such small quantities that they do not play any important part in the formation of the alkali deposits. Evaporation of a solution containing the above six factors might form nine simple salts and a great number of double salts and hydrates, besides mechanical mixtures of all these in any proportion.

It would be impossible to prove what the conditions were under which beds of pure salts like the Wyoming alkali lakes were found, because the concentrations, proportions and temperatures at the different stages of formation are all unknown and it is evident that theoretically the same result could be obtained by many different reactions. Since none of the compounds are absolutely insoluble and since nature has unlimited time and reagents, we must regard any reaction as reversible, however completely it may go in one direction in the laboratory. But it is not impossible that a consideration of the simpler reactions of these factors may throw some light on the probable way in which pure salt deposits have been formed. Starting with a solution such as our natural waters containing the bases calcium, magnesium and sodium and the acids carbonic, sulphuric, and hydrochloric, the most insoluble compound possible would be first precipitated. This is calcium carbonate or a mixture of calcium and magnesium carbonates forming beds of limestone or dolomite. Calcium carbonate is, however, much more soluble in the presence of other salts than we usually think and magnesium carbonate is found in large amounts in water of the state containing much sodium carbonate. The calcium sulphate would next be deposited in the form of gypsum. Beds of gypsum of great thickness exist in many parts of the state, as at Red Buttes, where plaster of Paris has been made for many years, and it is abundant in most of the soils. In the Laramie Plains gypsum was found at intervals in boring the University artesian well to the depth of a thousand feet. If, as is generally assumed, sodium was originally extracted from the rocks in the form of carbonate, the absence of this salt in most of the state could be accounted for by the well known reaction between sodium carbonate and calcium sulphate to form sodium sulphate and limestone. This has been used in practical agriculture on the advice of the California Station to eliminate the more injurious black alkali or carbonate.' In parts of the state where sodium carbonate is found, as at Green River and Johnstown, gypsum is of course absent, or nearly so.

If now we regard both the calcium and the carbonic acid as completely precipitated, we have left as possible compounds magnesium chloride and sulphate and sodium chloride and sulphate. Of these, magnesium chloride is by far the most soluble at ordinary temperatures and would therefore be the last salt deposited and the first washed out from an alkali bed. In all the alkali and waters analyzed in the state the sulphates are in large excess over the chlorides, so we may regard magnesium chloride as practically absent and the salts formed would be only magnesium sulphate, sodium sulphate and sodium chloride. Analysis shows that almost all of the alkali of the state consists of these three salts in varying proportions. There are beds of pure magnesium sulphate and sodium sulphate, but so far as I am aware there are no deposits of sodium chloride. Brines exist but do not form beds.

These three salts are about equal in solubility at ordinary temperatures and on complete evaporation would be deposited together, which is usually the case. But their relative solubility is greatly changed by a variation in temperature, as the sodium sulphate is much more soluble in warm than in cold water, while with sodium chloride there is little difference, so the fall in temperature in a single night, which is often great in the arid region and high altitudes, would precipitate a thick layer of crystallized sulphate which would not dissolve again the next day. In many of the strong alkali lakes this can be observed directly. In cold weather the bottom is covered with a thick bed of pure sodium sulphate, above which is a saturated solution containing much chloride. In warm weather part of the bed goes into solution again. In winter Great Salt Lake throws up on the shore sodium sulphate crystals in banks looking like snow drifts. The magnesium sulphate beds might have been formed in a similar way.

It is possible by this system of simple reactions to explain the alkali deposits, although it is evident that they can be theoretically accounted for in other ways, and it is not necessary to assume that similar deposits have an identical origin. All that is intended is to show how from a dilute solution of many substances, such as ordinary spring or river water, the salts actually found could be formed and not the many others theoretically possible. It is not necessary to assume, as many have done, that the original rocks corresponded in composition to the salts left in evaporation of their leachings. With the conditions that prevail in Wyoming, an annual evaporation about five times as great as the rainfall, a porous soil and scanty vegetation, such an accumulation and differentiation of salts is quickly accomplished. One can start with a good soil and irrigate it with water of ordinary composition and in a few years crystals of pure sodium sulphate may be picked off the surface. This experiment has unfortunately been repeated on a great many acres.

The principal source of the alkali is not, however, the water used in irrigation, but the beds of soluble salts that are deep in the soil. As soon as water is put on the land these salts are drawn to the surface by evaporation. The fact that the soils of the valleys are saturated with alkali ought to be taken into consideration in the proposed establishment of reservoirs. If these are of wide extent the great evaporation of these regions would concentrate the water and so increase the per cent of alkali it contains. To this the alkali leached from the surrounding soil will be added and there is danger that water so stored would become injurious rather than beneficial to the land which received it.

ABSORPTION OF WATER FROM ALKALI SOLUTIONS BY SEEDS.

Before we can hope to do much to mitigate the injurious effects of alkali on plants we obviously must know what that effect is. How does the alkali limit the plant? Although it will be many years before any complete answer can be given to that question, yet the study of the subject by the Station has cleared up some of the simpler points. For the simplification of the problem it was divided into two parts, the effect of alkali on the germination of the seed and its effect on the growth of the plant. Only the first part of the work will be made public here.

The effect of alkali on the germination of seeds depends on three things, the kind of seed, the kind of alkali, and the concentration of the alkali solution. Sometimes the seeds in alkali solution are killed, sometimes they germinate but very slowly, sometimes they germinate more quickly as compared with those in pure water. The usual result is that the seeds are delayed in germination for a long time. Now in Wyoming the season is too short anyway, and even a few days' delay will make the difference between a crop and a failure.

A necessary preliminary to germination is the absorption of water, and it seemed likely that the retarding effect of the alkali on the germination was due to its hindering the seed from absorbing the water it needed. Experiments showed that this was the case, and work on this line has been carried on in the chemical laboratory for about three years now. The technical details will be published in the annual report of July next, but a table showing the results of one of the experiments is here given to show how such work is carried on. Wheat was the seed experimented upon in this case and an equal weight of it was put into solutions of the common alkalies of various strengths, pure water, and a solution of sugar introduced for comparison. It was found that the absorption of water was influenced not by the kind of alkali or the strength of the solution but purely by the osmotic pressure. Osmotic pressure is not generally understood and in fact is a comparatively new conception in science, but it is easy to explain what it means. In this case it simply means that the water passes through the little coatings in the seed openings more easily than the particles of salt, and consequently a seed will take up water more rapidly if no salt is present. To give a rough illustration, a pump supplying city water works will get more water through the screen of the intake pipe if the holes of the screen are not partly clogged with sand and drift wood. In this experiment, the solutions of sugar, sodium sulphate, magnesium sulphate, and sodium chloride were so made as to have the same osmotic pressure, and it will be seen from

Amount of Water Absorbed by Wheat from Salt Solutions.

No.	Solution of	Per cent of salt.	Osmotic pressure, atmospheres.	PER CENT WATER ABSORBED BY WHEAT.											
				12 hours.	24 hours.	36 hours.	48 hours.	60 hours.	72 hours.	84 hours.	96 hours.	108 hours.	120 hours.	132 hours.	144 hours.
1.	Pure Water	0	0	331	426	492	516	546	557	583	601	601	617	623	623
2.	Sugar	1.43	1	334	432	493	513	543	552	582	598	608	614	620	617
4.	Magnesium sulphate	.34	1	314	401	463	493	521	547	567	577	596	606	608	602
6.	Sodium sulphate	.24	1	321	416	478	488	532	544	577	583	601	619	617	607
8.	Sodium chloride	.12	1	340	419	495	500	518	537	569	579	583	591	593	603
3.	Sugar	14 30	10	263	279	418	442	450	460	467	478	481	481	481	479
5.	Magnesium sulphate	3 94	10	312	384	433	455	456	469	479	489	489	489	487	487
7.	Sodium sulphate	2 66	10	297	383	436	440	451	459	463	479	483	486	483	492
10.	Sodium chloride	1 39	10	315	397	443	449	466	470	472	472	476	474	482	500

the table that the wheat absorbed just about the same amount of water from each of these in the same length of time. Sodium carbonate ("black alkali") acts differently, for when it is strong it attacks and destroys the seeds themselves. Some seeds, too, give quite different results. Beans absorb the same amount of water when put into a saturated solution of common salt as they do when put into pure water. The dissolved salt apparently passes into the bean as readily as the water and destroys its power of germination. Rye is intermediate between wheat and beans in this respect.

To decide the question whether the absorption of water is physical or physiological, comparative tests were made between living seeds, and seeds in which the power of germination had been destroyed by age, heat, or exposure to formaldehyde vapor. No difference between the living and dead seeds has been yet observed, so it appears that water is drawn into the seed purely by such physical forces as surface tension and osmotic pressure. It does not appear that the salts mentioned, except sodium carbonate, exert any poisonous influence on the wheat. It germinates readily when removed from the alkali solutions and put under favorable conditions.

The absorption of water is retarded and diminished by the presence of salts in the water, but not prevented. This is due to the fact that the seed allows the salt to pass into it though not so readily as the water. The volume of the swelled seed and the amount of salt they contain has been determined and it appears that in strong solutions enough salt is absorbed to make the solution inside the seed nearly the same strength as that outside. In this way the resistance to absorption of water due to osmotic pressure is diminished. The same means of obtaining water from a strong salt solution is probably used by such plants as the salt sage, which contains a large amount of mineral salts. This has the double advantage of aiding the plant to draw water from the soil and to keep better what water it has, because the salts dissolved in the sap lessen the evaporation.

The experimental work here outlined is being applied to plants as well as seeds, with the hope of finding out why it is that crtain plants thrive in soil containing much alkali and little water, while others, sometimes of the same genus, will die under these conditions. Experiments on low forms of life show that they can be made immune to the deleterious effects of a very great osmotic pressure by slow changes and selection, and this suggests the possibility that the same can be done for higher plants, and useful vegetation be grown to cover the acres now given over to greasewood or samphire.

Alkali Investigations.

B. C. BUFFUM.

FIELD EXPERIMENTS.

The experiments or lines of investigation under way in the field were outlined in Bulletin No. 29 of this station. While it can not be said that any of this work has been completed, some results have been obtained which are of interest. The productive area of the Station Farm is continually being encroached upon by the rise of alkali salts on the lower parts of the land. At the same time the greatest care has been exercised in our irrigation. It can not be laid to over-irrigation, or the careless handling of the water used. We know of no way to effectually prevent the accumulation of alkali salts upon low lands which have no drainage outlet. It is possible to irrigate land which has considerable slope without allowing any appreciable amount of waste water to escape, but, unless the land is level, some of the water finds its way through the soil or subsoil down the slope, carrying a quantity of the soluble salts with it. If there is good drainage the salts are washed out of the soil into streams and carried off. Where there is no outlet of this kind a reservoir is formed in which the salts accumulate just as water collects in a lake bed. As more of the salts are washed from the higher ground the accumulation increases and more land is added to the unproductive alkali waste.

Where the process of leaching has not begun the salts naturally occur distributed through the soil in comparatively small quantities. Small amounts of these salts are beneficial, either acting directly as plant food or indirectly aiding in the process of plant nutrition. The fact that the soluble portion of our soils has not been leached out and carried away by excessive rainfall accounts for such lands being almost if not quite as rich and lasting as the soils along the Nile, which receive an annual supply of leachings and sediment from the head waters of that stream. However, when our lands are brought under irrigation and cultivation there seems to be no way of keeping the soluble salts scattered through the soil as they were originally. When water is applied they move downward. By the percolation of water through the soil, the salts are carried from one place to another, accumulating where the water accumulates. When the water evaporates from the surface the salts in solution are left behind and more water coming up from below continually adds its freight of salts, leaving them where they can do the most damage to crops. This simple principle of the movements of alkali salts in the soil along with the water furnishes the key to any preventive treatment which must be along one of the following lines:

1. Irrigation with water free from salts.
2. Preventing seepage.
3. Draining the water from below.
4. Cultivating or treating the surface in such a way as to prevent evaporation, which brings the salt to the surface.

Over-irrigation and the lack of most intelligent and thoughtful management brings about rapid and wide-spread destruction of the most fetile lands. Good natural or artificial drainage will enable the farmer who properly crops, cultivates, and irrigates his land to prevent any damage from alkali, providing the water with which he irrigates does not bring large amounts of salts to his soil.* But there are places without good, natural drainage where artificial drainage will be too expensive for years to come and where alkali is accumulating more or less rapidly. As yet the farmer has no market for his crop of salts and unless he can so treat the land that it will bring some return he is better off without the useless acres upon which the taxes are the same as upon the rest of the farm.

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*For data of the amount of alkali salts actually deposited upon some soils from the water used in irrigation, see Wyoming Station Bulletin No. 24. "Water Analyses.")

All this discussion leads up to the point I wish to make. Although we may know of no easy or cheap method of reclaiming such lands so all crops will thrive upon them we may make them productive by introducing plants which will grow in the presence of large amounts of alkali salts. Professor Hilgard has accomplished a great deal in introducing alkali resisting plants to cultivation in California. We have been experimenting with such plants for some time and are now able to report upon a few of them.

We have found very few useful plants which will grow where the soil contains so much alkali that an incrustation is formed on the surface. Incrustation of our ordinary white alkali on the surface is usually marked, at least during dry weather, where there is as much as one and one half or two percent of salts in the first two inches of soil. Such an amount of salts will prevent the growth of any of the cereals or of alfalfa. Barley and rye seem to stand more alkali than will wheat or oats. I believe barley, rye, or alfalfa will grow in the presence of as much as one percent of our ordinary white alkali, (sulphates of soda and magnesia), in two inches of surface soil, providing the water level is not nearer the surface than two or three feet. Usually where there is so much alkali as this, which has accumulated from irrigation above, the water comes near the surface, leaving the soil saturated most of the time. Where this occurs less than one-half of one percent of salt along with the water is fatal to such crops. Upon soils containing about two percent of salts in the first two inches we have tried, without success, rye, wheat, barley, oats, alfalfa, and Russian sunflowers.

Brome grass and red top have been partially successful. Our experiments with them have not been extensive enough to reach final conclusions.

The following alkali-resisting plants need special mention.

SALT SAGES OR SALT BUSHES (Species of Atriplex).

Just now many enterprising seedsmen are advertising the "Australian Salt Bush," (*Atriplex semibaccatum*), urging farmers to purchase the seed for sowing upon their alkali lands. It has been very successful in California, where it produces large yields of forage. However, it is a warm climate plant and does not succeed in Wyoming. We have given it careful trials at Laramie, Lander, and Sheridan. At Laramie it only made a small growth the first season. At Sheridan its growth was thrifty the first summer. The Superintendent of the Sheridan Farm, Mr. Lewis, stated that he had difficulty saving the plants from destruction by what he called "the common beet bug," or "the long gray potato bug."[*] By a liberal use of Paris green, the insects were destroyed. The plants made a spreading growth, almost covering the ground by the time of frost. None of the plants lived through the winter at any of the places they were tried.

There are a number of species of atriplex, closely related to the Australian Salt Bush, found native in the State, which grow in alkali lands. Some of them are of much importance as forage plants. The more promising of these are being studied by our Botanist, who is co-operating with this department in attempting to introduce them into cultivation and determine their value for wider distribution.[†]

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[*] This insect is one of the Blister Beetles (*Epicauta sp ?*). It has done considerable damage to beets and potatoes in parts of the state, especially in Sheridan and Crook counties.

[†] A valuable contribution to our knowledge of the forage plants which grow in the alkali soils of our state is contained in Bulletin No. 13 of the Division of Agrostology of the United States Department of Agriculture, entitled "The Red Desert of Wyoming and Its Forage Resources," written by Professor Aven Nelson of this Station. In this bulletin the salt sages and other plants found growing in alkali places are discussed, with data relating to their value as food for range stock and suggestions as to usefulness of certain species if brought under cultivation.

Plants of this character, which take up large amounts of the alkali salts, will naturally aid in removing the salt from the soil with the crop. Stockmen have long appreciated this property of the salt sage, regularly making use of it as food for their range stock, to avoid the necessity of purchasing common salt for them.

ENGLISH RAPE.

Dwarf Essex Rape was planted upon the Experiment Farm two seasons, being sown upon strong alkali soil which would not produce grain or alfalfa. In 1894 a rather thin stand was obtained. The soil was very damp all summer. About the first week in August the rape began to make a rank growth. When cut on September 3 it yielded at the rate of a little over fourteen and one-half tons of green fodder per acre. In 1896 rape planted on strong alkali ground also made excellent growth. Rape is attracting much attention as a soiling crop or as forage, especially for sheep. While it is an annual plant it may prove of value upon alkali soils in the state.

BOKHARA OR WHITE SWEET CLOVER.

(*Melilotus alba.*)

At Laramie and at Sheridan sweet clover has made large growth upon strong alkali soils. Unfortunately it seems to be of little or no value unless it be as a honey plant for bees, though I have been told it is cut and baled for cattle food in parts of Utah. Heretofore I have warned our farmers not to plant this clover on account of its spreading to places where not wanted and becoming a troblesome weed, where allowed to ripen its seed.* Recent experiments indicate that it may be of some value for alkali land, to improve the soil before planting other crops. In 1897 an alkali plat was planted to sweet clover. This season, 1898, at the time it was in blossom it had produced 18.4 tons of green tops per acre, and was plowed under for green manure. The average height of the plants was 5.2 feet and computed as dry hay the yield was over four and one-half tons per acre. It was difficult to plow under so large a crop. Like other leguminous crops this clover takes nitrogen from the air by means of the little tubercles on the roots. The roots of those plants which we examined were literally covered with these tubercles, which indicates that sweet clover may prove of value as a nitrifying agent. Adding nitrogen to the soil by the roots, combined with plowing under the rank growth of tops to improve the soil tilth and add humus, it is believed will make the land much more productive.

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*See Wyoming Station Bulletin No. 16, page 236. In this connection Professor Hilgard has told me that in California, where sweet clover became a weed in wheat fields, millers refused to buy the wheat, as it became tainted with the strong, peculiar odor of the clover seed and complaint was made that the flour from such wheat made gingerbread. If planted for any purpose it should not be allowed to spread, but all plants should be cut when in bloom to prevent the production of seed. It is a biennial, producing its seed the second year and then dying.

SUGAR BEETS.

Sugar beets thrive well upon soils strongly impregnated with alkali salts. It is claimed that excess of chlorides in the soil upon which beets are grown, seriously interferes with the crystallization of the sugar in the process of manufacture. This would give no trouble here as only small amounts of chlorides are present and the sulphates do not have the same effect.

As yet we have no sugar factories, but the beets are invaluable as stock food.* Where fattening stock or milch cows are to be fed during the winter, it will pay to raise sugar beets to mix with other food. The beets may be raised upon the alkali part of the farm, but in order to produce large yields the land should be fertilized the same as any other soil upon which beets are to be grown.

In 1897 and 1898 we grew sugar beets upon soil practically free from alkali, and upon soil containing so much alkali that ordinary crops would not grow. The composition of the alkali as shown by analysis made by Mr.

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*See Wyoming Station Bulletin No. 30, "Stock Feeding at Lander."

Fairfield in the spring of 1897 was Sodium and Potassium Chlorides 14.39%, Sodum Sulphate 50.16%, Magnesium Sulphate 20.03%, and Calcium Sulphate 15.41%. (Bulletin No. 29, p. 228). The soil was not fertilized in either case and the yield was much larger on the alkali soil. In 1897 the beets were analyzed by the U. S. Department of Agriculture, showing a large percent of sugar and high purity. The results are given in the following table:

Sugar Beets at Laramie.

Year.	Kind of Land.	Yield Per Acre, Pounds.	Sugar in Beet. Percent.	Purity
1897	Without alkali	11,643	19.0	89.2
	Strong alkali	14,486	19.7	88.1
1898	Without alkali	5,985	. . . . . .	. . .
	Strong alkali	12,632	17.5	. . .

RECLAMATION OF ALKALI SOILS.

The old saying that "an ounce of prevention is worth a pound of cure" is in place here. While it may be impossible to prevent the accumulation and rise of alkali on certain portions of the farm, by taking the matter in hand early the time of land becoming unproductive may often be almost indefinitely posponed. The low ground where it is expected alkali will first come to the surface should be kept in some crop, as alfalfa, which will shade the ground the greater part of the time, or planted to such crops as can be thoroughly cultivated to loosen the surface and prevent evaporation.

The only experiments we have made in reclaiming have been by open ditch draining at Sheridan. In the summer of 1895 one hundred and fifty rods of open ditch were dug to drain about ten acres of the north-west corner of the farm. The soil of the farm is underlaid with hardpan and the leachings of alkali from the higher land followed along this hardpan to the lowest part, where the salts came to the surface.

A part of the time the water level was as high as, or above the surface of the ground, and so much alkali collected there that even weeds which ordinarily thrive in the presence of such salts would not grow. In 1896, one hundred and twenty rods of additional ditch, two feet deep, was dug. The following extracts from the annual reports of Superintendent Lewis since 1895 indicate with what success the ditches have aided in reclaiming the land.

Extract from Report of 1895: "Our one hundred and fifty rods of ditch made during the summer will. I think, prove a great benefit to the alkali land. The water does not stand on the surface as it did."

Report of 1896: "Have made one hundred and twenty rods of new ditch, connecting with ditch made during 1895, which is doing much good in reclaiming the alkali land."

Report of 1897: "I consider our experiment with drain ditches has done and will do a great amount of good in reclaiming the land. Land that has been a white, smooth alkali bed for the last three years is now all covered with a heavy growth of weeds and grass, there being but little alkali which is apparent to the passer-by."

EFFECTS OF DIFFERENT ALKALI SALTS ON SEED GERMINATION.

As a continuance of the laboratory work on seed germination begun in 1896 and reported in Bulletin No. 29, Mr. W. H. Fairfield planned and carried out quite an extensive experiment to show the comparative effects of the different alkali salts. The credit for this experiment, the careful manner in which it was carried out and the full notes and tabulations of the results belong wholly to Mr. Fairfield, a large part of whose time was devoted to an enthusiastic study of the matter in hand. The experiment was finished in March of the present year and resulted in data of much interest and value. In order to substantiate the results obtained, a part of the experiment was repeated in November to check the results by bringing the seeds into contact with the alkali solutions in a different way. The general results of the check are so close to those in the original investigation that they lead to the same conclusions.

It is not our purpose here to make a full report of the experiment or a technical discussion of the results. There are some points of interest and value to the general reader, however, which we wish to note briefly. It is expected the full report of the work with diagrams and tables will be published in the annual report.

Seeds of wheat and rye were germinated in pure water and in solutions of carbonate of soda (black alkali), chloride of soda (common salt), sulphate of soda (glauber salt), sulphate of magnesia (epsom salt), and in sugar syrups the strength of which varied in the same percents as those of the salts used. Each of the salts used and the sugar were applied to the seeds in strengths of one tenth of one percent, four tenths of one percent, seven tenths of one percent, one, two, three, four, five, seven, and nine percent solutions. The sugar was used to throw light upon a technical point, which had been suggested by Professor Slosson, whether the retarding effect was due to the osmotic pressures exerted by the different salt solutions. The experiments show that this is the case and the fact throws much light upon the manner in which the injury to seed germination or plant growth takes place.

In these experiments it has been a most notable fact that small amounts of alkali salts are beneficial or at least that they accelerate instead of retard germination. No doubt small amounts present in the soil also assist in the life of the plant, either stimulating its growth or acting directly as plant food.

spire water and change the result. There are many irregularities in the table, probably due to difference in the pots themselves, but the general result is the same. From the pots containing no alkali 17.7 c. c. were evaporated each day, while the amounts of water lost from those pots containing 9 % solutions (equivalent to 2.2% alkali in soil with 24.5% moisture) was approximately one half as much.

Influence of Alkali Salts on Evaporation of Water from Pots.

c. c. of water evaporated per day.

SALT.	Percent. 0	Percent. 0.1	Per. cent. 0.4	Percent. 0.7	Percent. 1.0	Percent. 2.0	Percent. 3.0	Percent. 4.0	Percent 5.0	Percent. 7.0	Percent. 9.0
	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.
Water lost in c c.	17.7										
Sodium Carbonate.	17.7	17.5	14.7	13.8	12.1	12.6	13.1	*8.2	10.3	10.4	*8.5
Sodium Chloride.	17.7	15.4	14.1	14.0	12.3	10.9	9.7	9.5	7.9	8.9	8.5
Sodium Sulphate.	17.7	18.1	15.0	10.7	16.9	12.5	10.9	7.3	8.2	10.1	9.6
Magnesium Sulphate.	17.7	17.4	13.1	11.4	13.1	11.4	9.2	11.3	8.4	8.2	6.5
Sugar.	17.7	11.1	15.4	13.6	12.9	12.4	10.2	10.1	9.7	9.4	8.8

*Average for 9 days.

UNIVERSITY OF WYOMING.

Agricultural College Department.

WYOMING EXPERIMENT STATION,

LARAMIE, WYOMING.

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JANUARY, 1899.

The Trees of Wyoming and How to Know Them.

BY AVEN NELSON.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyo.

Wyoming Agricultural Experiment Station.

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1. **AMONG THE TREES.** *A Wyoming Home, Ft. Bridger.*

THE TREES OF WYOMING

. . . AND . . .

HOW TO KNOW THEM.

AVEN NELSON.

INTEREST IN NATURE.

> "In Nature's infinite book of secrecy,
> A little I can read."—*Shakespeare.*

HOW DEVELOPED.—We are, as a matter of course, indifferent to individuals and subjects to which we are strangers. Personal interest *in* and love *for* a thing are the result of intimate acquaintance with the worthy object. We *read* of love at first sight, but that affection that makes us willing to serve and defend the one or the thing that we cherish is evolved only through continued, helpful association. No subject of human interest has been promoted or defended worthily except by those who were its friends because they had real knowledge of its worth. The beauties of literature are evident to those only who through intimate knowledge of it are prepared to feel its power. Science is advanced by those who have comprehended its aims and are thereby made its devotees. Nature appeals with feeble voice to him who is a stranger to her. A Thoreau, a Burroughs and a Lubbock were cradled in her opulent lap and there learned the secrets that they so lovingly express.

THE CONDITION IN WYOMING.—In this fair state many of us seem to have been too busy to hold communion with Nature's visible forms. Because we lack knowledge concerning her we have been indifferent to her language and her inspiring beauty. With the sterner aspects that present themselves in bleak, wind-swept plain, in the roaring blizzard, and in the beetling crag of mighty mountain we are all familiar. We are often nearly strangers to her more lovely traits because these develop outside the beaten paths. Yet some there are who have learned to know, and knowing have learned to love her in her gentler moods:—have learned to know that here beneath the bluest skies, softest breezes play; that fragrant flowers of rare beauty deck every hillside; that sweet streams murmur in every mountain valley; that many a crystal lake mirrors sky and shore; that emerald mosses occur in every shaded nook and lichens cover every rock and crag with gayest yellow and softest gray; that stately trees crown many a hilltop and forests dark and dense clothe in solitude every mountain side.

We are rich in those elements of natural scenery which appeal to the higher sentiments of our nature, but too often we are forced to live so apart from them that we miss much of the good that ought to come to us from that source. Three-fourths of the people of Wyoming live in towns upon the various lines of railroad. Two-thirds of these towns are situated on the open and comparatively barren plains. In some of these many of the first settlers thought of them simply as temporary places of abode. This, added to the natural difficulties encountered in adorning the home and public grounds, left our homes in desert-like places and our lives impoverished from a lack of those things to which our sentiments would cling through all the passing years.

Who among us, of maturer years, does not recall with interest or almost worshipful affection some stately tree, shaded lane or secluded forest nook of our childhood's home? But there are towns in our state *today* without a tree or shrub or even a bit of lawn. Our children are missing that element of refinement which comes from beautiful surroundings outside the home. Girls and boys are nearing maturity in some localities in the state to whom any tree would be of interest and to whom a glimpse of a fruit tree in blossom would be as a glimpse into Paradise. There are homes in abundance where the sentiment expressed in the following lines would find no answering chord:

"Woodman spare that tree,
  Touch not a single bow;
In youth it sheltered me
  And I'll protect it now."—*Morris*.

INCREASING INTEREST ELSEWHERE.—In many parts of America, Nature has been so prodigal in the distribution of her trees that what we owe to them has been poorly appreciated. Just now, however, a great wave of interest and enthusiasm is sweeping over the country which it is hoped will make trees and forests as cherished here as they have been for centuries in the old world. Shall not Wyoming have a part in this growing interest? Shall we not learn something of the treasures of our hills and mountains? Shall we not bring into our lives and into the lives of our children some part of the enjoyment and help that comes to those who are in touch with Nature? Sir John Lubbock says: "The love of nature is a great gift, and if it is frozen out or crushed out, the character can hardly fail to suffer from the loss." If this be true it would be well for us to remember that this ele-

II. "THE OLD HOME."

III. "THE NEW HOME."

TREES VS. TREELESSNESS.

ment in our character, if it is to grow or even to live, must have something to feed upon. We must surround ourselves with those natural elements of beauty to which our sentiments can go out. These are prodigally abundant in our mountains, but Nature has dealt less kindly with our great plains.

DEVELOPMENT OF INTEREST.—We must look before we can expect to see; we must see before we can know; we must know before our interest will be aroused; our interest must be aroused before we will exert ourselves to bring about the clothing of even our home grounds with those grandest elements of beauty in any lanescape—trees.

"No tree in all the grove but has its charms."—*Cowper.*

Knowledge brings interest, interest brings action. But to whom may we appeal to disseminate this knowledge? Surely to all who have ever loved the trees of the old home; to all whose children are growing to manhood or womanhood in any treeless town; to all whose ranch homes lie upon the wind-swept plains, and especially to those into whose hands we are entrusting the mental training of our children. Yes, we can certainly hope that our teachers will interest themselves in this branch of nature study that promises so much of good to the individual pupils and to the community as a whole.

A CASE IN POINT.—The early explorer who ventured beyond the Missouri and the pioneer settler in what is now Nebraska found the whole trans-Missouri region a treeless, wind-swept plain, the more western part at least being included in the hypothetical "Great American Desert." Little by little the boundaries of this desert are contracting and we may hope for its ultimate extinction.

Nebraska, recently the treeless state of the Great plains, is no longer treeless. Orchards here, shady lanes there, and groves yonder meet the eye of the traveler as he is whirled across its broad acres. No longer can the eye follow the landscape until the gray of the undulating hills blends with the gray of the sky on the distant horizon. Its transformation in one generation from dreary treelessness to restful though animated homelikeness must be considered one of the achievements of the age. This result is certainly one of the factors that have contributed to the greatness of our neighboring commonwealth.

One of the most potent influences in bringing about this desirable result has been the awakening of a public sentiment, in regard to trees, the like of which has nowhere else in the United States been secured—and all this largely through the schools. The school touches every home. Let the light of enthusiasm shine out in the teacher, then soon the whole school is ablaze with eagerness and the reflection extends even beyond the neighborhood bounds.

This sentiment for trees and enthusiasm for tree planting reached its climax in Nebraska in the years immediately following the establishment of Arbor Day, at the suggestion of Hon. J. Sterling Morton. He will be gratefully remembered for that act long after his other public services have been forgotten, not only in Nebraska but in all the states where Arbor Day has become an established institution—an institution the observance of which is now all but universal.

Speed the day when interest in this subject shall sweep over Wyoming, and, to hasten its coming, may we not hope to enlist the co-operation of all the teachers within our borders? Pupils and parents will alike be interested in the trees of the state in their homes and in their relation to ours. In what way can we better begin to develop this interest than by learning to know them? We shall then soon find springing up a desire to enjoy, to own and to protect them.

FOREST RESERVATIONS.

"I regard the forest as an heritage, given to us by Nature, not for spoil or to devastate, but to be wisely used, reverently honored, and carefully maintained. I regard the forest as a gift entrusted to us only for transient care during a short space of time, to be surrendered to posterity again as unimpaired property, with increased riches and augmented blessings, to pass as a sacred patrimony from generation to generation."—*Baron von Mueller*

The setting aside by the General Government of large tracts of forest lands, in various parts of the United States, to be preserved perpetually as forests, has met with much favor in most parts of the country. Some criticism arose at first from a few who feared that private interests might suffer or that certain industries, such as mining, might be hindered in their development. Now, that fuller information has shown that the purpose of this forest legislation is wholly beneficent and that it is not intended that these laws shall work a hardship on any one, even those who were at first inclined to criticise are now warm advocates of the policy. The early criticism proves to have been a good thing. The attention of the whole country has been called to the great benefits we derive from forest covered lands.

INFLUENCE OF FORESTS.—While this is not the place for a discussion of this question, yet it may be well to mention a few of the points. First, it is well known that large, wooded areas exert a great influence upon the climate of adjacent regions, i. e., temperature, moisture and healthfulness are affected by them. Of greatest importance, however, is their conservation of moisture whether it falls in the form of rain or snow. To the wooded summits and slopes of our mountains we owe the fruitfulness of the valleys and plains below. The rain is taken up by the loose soil and leaves and sinks into the crevices among the rocks. Days and even weeks pass by before it all finds its way into the brooks and streams. When it does reach these it literally filters into them as clear and sparkling as if it had verily been distilled. The snows of winter, protected in the shade of the dense woods and piled in great drifts in the canons, linger even in the lap of summer, feeding slowly but surely the many life giving streams upon which the vegetation in the valley and on the plain depends. It will easily be seen that the forests hold back what would otherwise be flood waters in the streams that drain the region. So it happens that communities hundreds of miles from the great forest reservations are interested in their perpetuation.

Contrast the condition in open country or where the timber has all been removed. Rains that fall upon naked slopes run off with a rush, carrying the soil off with the water and washing out gullies, ravines and even canons. In open regions we have seen the muddy streams overflowing their banks after a shower or following the melting of the spring snows. The soil is all washed away, making worthless many a once valuable acre. The water courses in such regions, during dry periods, instead of being clear, flowing streams are little more than stagnant, muddy pools.

Wyoming is fortunate in the possession of several heavily forested mountain ranges. She is thrice blessed in having within her boundaries three regions deemed worthy of protection and preservation by our Government. Let us hope that these may remain to bless the people, both within and without our boundaries, through all time to come. May national interest demand the preservation of the mighty forests that crown the summits and cover the slopes of the Wind River mountains also.

Nature has further made amends for our wind-swept plains by giving us a fourth Forest Reserve, one in which the whole world has an interest as the great Wonderland. This is the region where are conserved the waters that feed the rivers of a continent. In Yellowstone Park are the headwaters of three great river systems, the Missouri, the Columbia and the Colorado, not to mention many smaller streams that are ultimately tributary to these.

A PLEA FOR A PROTECTIVE POLICY.—Shall not we, as citizens of the state which has most to gain, loyally support a policy that means so much to our arid plains? Under the past reckless management, or rather total want of supervision, enough timber has been destroyed by forest fires (often wantonly kindled) to bountifully supply the entire state for centuries. Under a wise protective policy our forests can be made to yield all the timber that we can possibly use for domestic purposes, without in the least impairing their beauty, extent or productiveness. If we learn to know our forest resources and their value to us, then we shall come to appreciate them so highly that we shall stand as a unit for their protection from those who would destroy them for private gain. We shall also desire to protect them from the consequences of the present reckless indifference that allows the destruction of thousands of acres of valuable timber by fire. Who has not felt the desolateness of what would otherwise be the most charming scenery were it not for the dead and fallen trees that strew the blackened slopes. The writer has in mind two places in the state, making some pretensions as mountain summer resorts, which, with their limpid lakes, would have all the elements of natural beauty were not the whole effect marred by unsightly, blackened stumps and progress impeded on every hand by the tangled, fallen timber.

NAMES.

COMMON NAMES.—That it would be a most desirable thing to have a good expressive English name, not only for our trees but for all the important plants, is freely admitted by all. In fact it seems so desirable that great effort is being made by those who think and write upon these subjects to hit upon some good "common name" upon which all can unite. The difficulties encountered, however, are great, for not only do most plants have different common names in different localities but, what is worse, very different plants have the same common name. To illustrate: One of our commonest trees, Lodge Pole Pine, is also called in Wyoming, Tamarack and Black Pine; in Utah, Prickly Pine; in Montana, White Pine; in Colorado, Spruce Pine, and, possibly in other places by yet other names. Then these names are also applied to other trees, as, for instance, Tamarack to one other species of Pine and to two different species of Larches and possibly to other trees. How then shall we know what tree is meant when we hear a name? No way suggests itself except that we must, as a people, agree upon the most expressive, available name. Then we must learn to know that tree and must apply no other name to it and that name must be applied to no other tree.

The names suggested in this bulletin are not original with the writer but such are chosen from those in common use as have secured the approval of men who have given much time and thought to this subject.*

LATIN NAMES.—The scientific names have a great advantage in that only one name can properly be applied to the plant in question and that the oldest one. By this name the plant must be known the world over. Such a name consists of two parts, the first or generic name which, in a way, corresponds to a person's family name and the second or specific name which points out a particular kind much as a given name points out a particular person. To illustrate: The Pines belong to the genus *Pinus;* the Cottonwoods are *Populus.* To point out a particular kind (species) another word is added, as *Pinus flexilis* (The Limber Pine) or *Populus balsamifera* (Balm of Gilead). It is customary to add the name (or abbreviation of it) of the person who first describes the species or brings the right generic and specifis name together. Thus the two just given should be written *Pinus flexilis* James, and *Populus balsamifera* Linn.

Now these Latin names are not so difficult to learn or to understand as most people imagine. They are in fact more easily remembered than common names for they are often descriptive of some character of the plant as may be seen in those given above.

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*Mr. George B. Sudworth in the excellent bulletins of the Division of Forestry, U. S. Dept. of Agriculture is doing much to bring order out of the chaos of common names. I am glad to acknowledge my indebtedness to Bull. No. 17 of that Div.

In the following pages the scientific name is printed in parenthesis, in italics, under the common name. It is hoped that those who really wish to know our trees by the names now accepted for them everywhere will familiarize themselves with these names in particular.

THE TREES OF THE STATE.*

TREE DEFINED.

Woody plants which continue to grow for some years are known either as shrubs or trees. Size is usually made the line of separation between the two but the form of growth is quite as characteristic. The following quoted definition seems to express the commonly accepted idea of a tree: "Trees are such woody plants as produce in nature a single trunk, branching more or less above the ground."† Accepting this definition, there are included in the following list a few that are comparatively small, such as the Buffalo Berry and the Choke Cherry. But even these have the true tree habit and may properly be included.

***Special attention is called to Bulletin No. 38 by Prof. B. C. Buffum, recently issued by this Station. That bulletin bears the title "The Cultivated Shade and Forest Trees," and considers in detail the characteristics and relative value of the various trees that are used on home and public grounds. Methods of transplanting and cultivating are also considered.**

Since native trees must be so largely used for decorative purposes both on the home and public grounds it seems probable that a bulletin on how to recognize them may be welcome. For this reason this bulletin is made to follow so closely, in order that the two may supplement each other.

†Bull. No. 14, U. S. Dept. of Agriculture, Div. of Forestry.

KEY TO THE GENERA.*

§Leaves needle-shaped:
†In small bundles of two to five....................1. Pine (*Pinus*).
††Singly and with sharp points....................2. Spruce (*Picea*).
†††Singly and with blunt points.....3. Douglas Spruce (*Pseudotsuga*).
§§Leaves short, scale like..........................4. Juniper (*Juniperus*).
§§§Leaves with a true blade and stem (petiole):
†Fruit an egg shaped capsule, containing seeds furnished with a tuft of white, silky hair:
‡Buds resinous....................5. Cottonwood (*Populus*).
‡‡Buds not resinous.......................6. Willow (*Salix*).
††Fruit a nut:
‡Small, in a close, cylindrical or oval cluster:
—Nutlet winged.................7. Birch (*Betula*).
— —Nutlet not winged..............8. Alder (*Alnus*).
‡‡Large, with a cup, singly or in clusters of 2 to 3.......
..................................9. Oak (*Quercus*).
†††Fruit with conspicuous wings :
‡Produced in pairs.......................10. Maple (*Acer*).
‡‡Produced singly......................11. Ash (*Fraxinus*).
††††Fruit fleshy, drupe like (Stone fruits):
‡Seed single, large, flattened } 12 { Plum } (*Prunus*).
‡‡Seed single, small, round } 12 { Choke Cherry } (*Prunus*).
†††††Fruit fleshy, a pome:
‡Seeds large for the fruit, bony........13. Haw (*Crataegus*).
††††††Fruit fleshy, berry-like:
‡Seeds several, small........14. Serviceberry (*Amelanchier*).
‡‡Seed single, large, pulp dry....15. Silver Berry (*Eleagnus*).
‡‡‡Seed single, small, pulp juicy.......................
.....................16. Buffalo Berry (*Lepargyraea*).

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*The small number of genera and species of trees represented, it should be noted, does not indicate a scarcity of trees nor the absence of forests. It simply indicates that the climatic conditions on these high plains and mountain ranges are unsuited to any but the hardier forms. Scarcity of kinds does not mean scarcity of trees. One-sixth of the State or about 10,000,000 acres is more or less forest covered. Then too, what we lack in kinds of *trees* is more than made up to us in the wealth of species of ***shrubs*** and ***herbaceous vegetation***.

Pine Family.

(Pinaceæ.)

"The pine is the mother of legends."—*Lowell.*

This family of plants includes much the larger part of the forest trees of Wyoming. Those belonging in other families are either small and scattering or form merely fringes on the stream banks—scarcely, if ever, a solid body of timber. The Pine Family, though far from being confined to mountainous countries and cold climates, is peculiarly characteristic of such regions. The greatest development and largest number of species occur, however, where a moderately cool temperature is combined with an abundance of moisture, as is the case on some portions of the Pacific coast. Of the sixty species which become trees, credited to Northwest America, only eight are positively known to the writer as occurring within our bounds.

This family has for a long time been known as the Cone-Bearers (*Coniferæ*), since the fruit of most of its members is somewhat cone-shaped.

The cone consists of a number of spirally arranged scales on which the naked seeds are borne. All the trees of this group are more or less resinous and are all evergreen. The four following genera, with the species under each, constitute the tree-like representatives of this family in this state.

1. PINES.

(*Pinus.*)

> "Ancient pines,
> Ye bear no record of the years of man,
> Spring is your sole historian."—*Bayard Taylor.*

The term pine is by most people applied very loosely. People, ordinarily well informed upon other subjects, utterly fail to discriminate between the most widely different cone-bearing trees. To most they are all simply "beautiful pine trees," whether they are Pines, Spruces, Firs, or more widely divergent forms. Even Junipers are sometimes included in this convenient term. To separate them is so simple a matter that our attention need be called to only a very few facts to enable us all to call a pine a pine, and a spruce a spruce, the moment that we see them. That both of them belong to the Pine Family need not mislead us, for it is common practice to use in the name of a family of plants the name of the principal genus in that family. A family may have many genera with well marked characters.

HOW TO KNOW PINES.*—Leaves in bundles of two to five (see illustrations); cones rather large and heavy, scales tough and woody; seeds borne on the base of the scales.

Three species occur, as follows:

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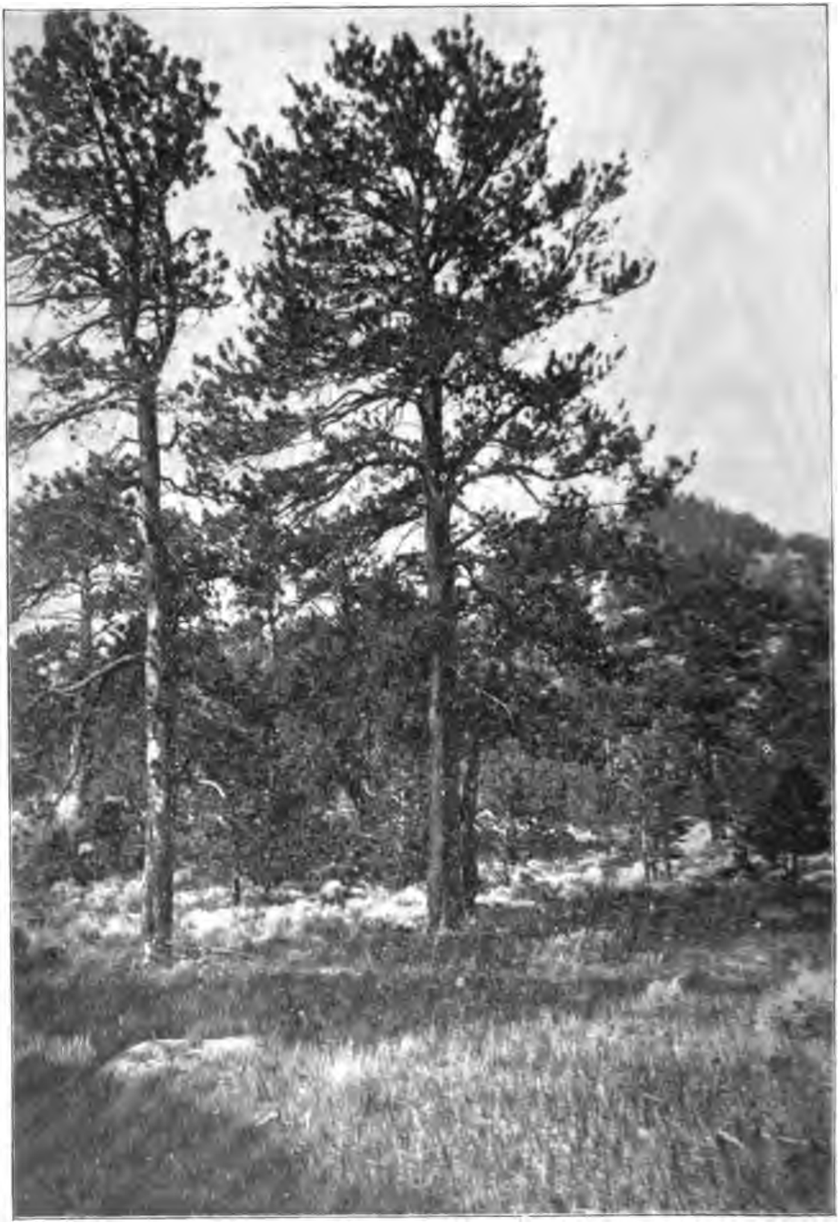
*Those who have occasion to use this Bulletin will please note that all statements and descriptions have reference to Wyoming trees. No effort has been made to discriminate except between our own species. The aim, ready reference, is best attained by few words. Full characterizations would hide the species in a mass of botanical terms.



IV. ROCK PINE. *Characteristic trees, 75 to 100 feet in height.*

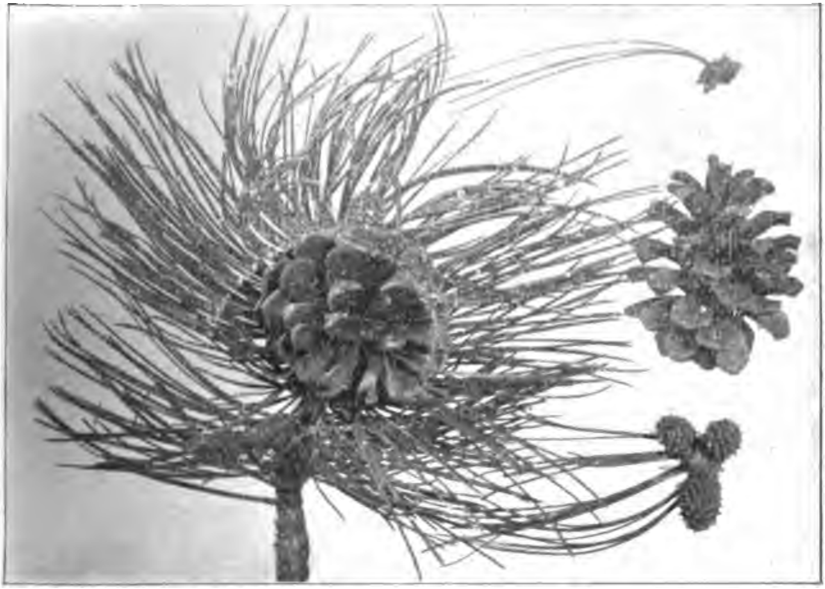
(1) ROCK PINE.

(*Piuus scopulorum* (Engelm.) Lemmon).

"Under the Yellow Pines I house,
When sunshine makes them all sweet scented,
An' hear among their furry boughs
The baskin' west-wind purr contented."—*Lowell.*

Description.—Leaves in bundles of three (rarely two), 4 to 7 inches long, slightly rough on the margins; cone 3 to 5 inches long, scales much thickened at the outer end and bearing a sharp, recurved prickle.

This is one of the largest trees of this state, attaining a height of 75 to 125 feet and becoming 3 to 5 feet in diameter. In some localities, however, as at Pine Bluffs and in the Dakota Black Hills, only comparatively young trees seem to be present. It is probably the hardiest and most widely distributed, though not the most abundant.



V. **ROCK PINE.** *Young and old cones and leaf-bundle.*

It occurs in all of our mountain ranges from the foothills up to about 8,000 feet. The wood of this pine is heavy and resinous, with a handsome grain. It is used to a considerable extent for domestic and commercial purposes. The tree may always be known by its stout, usually erect

VI. LIMBER PINE. *The Pine of the wind-swept slopes and hilltops.*

habit; well formed trunk; the long needles (leaves) which grow brush-like on the ends of the stems, and by the thickened, spine-tipped scales of the heavy cones. The names we often hear, Pitch Pine and Yellow Pine, fail to distinguish it, for there are some others bearing these names.

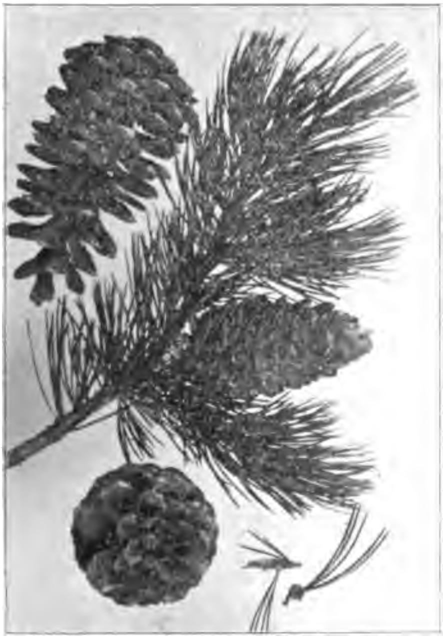
(2) LIMBER PINE.

(*Pinus flexilis* James).

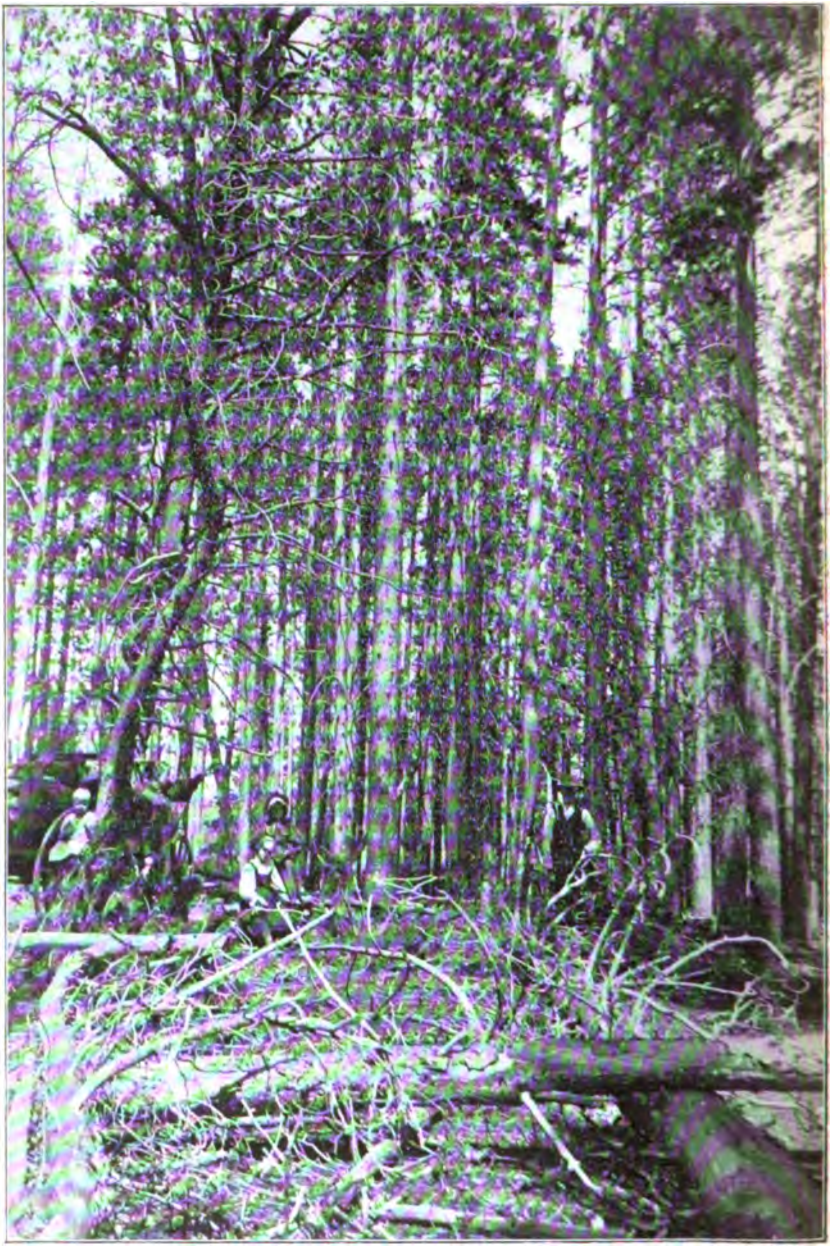
"In winter, when the dismal rain
Came down in slanting lines
And Wind, that grand old harper, smote
His thunder-harp of pines."—*Alex. Smith.*

Description.—Leaves five in a bundle, 1½ to 2½ inches long; cones light colored, long egg shaped, 3 to 4 inches, their scales with broad tips, not much thickened, widely spreading when mature.

Like the preceding, this is widely distributed and occurs in the hills and mountains in the most exposed situations. It forms a scattering growth or more rarely a continuous forest; is usually most abundant on east slopes, and is found at somewhat higher elevations than the preceding. It is rarely a well formed tree, except when it forms a dense forest, on account of the stress of weather that it has to endure in the exposed situations which it occupies. Its remarkably limber twigs, which no weight of winter snow can ever snap, enable it to withstand the fiercest tempest. So far as our species are concerned, the five-leaved bundles and unarmed cones will at once distinguish



VII. Limber Pine. *Cones, twig and leaf-bundle.*



VIII. LODGEPOLE PINE. *A characteristic forest of this species.*

it. It is largely used for fuel and possibly for other domestic purposes.

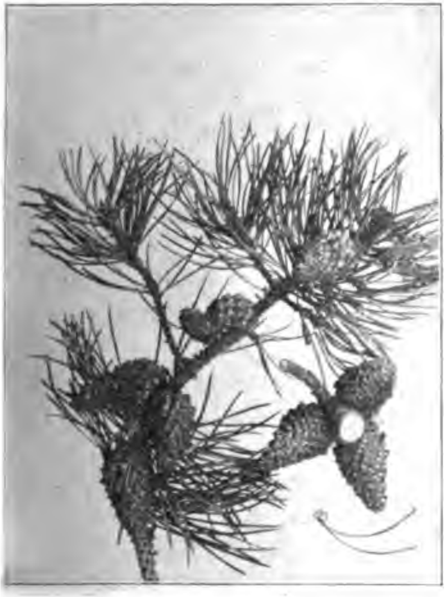
(3) LODGEPOLE PINE.

(*Pinus Murrayana* "Oreg. Com.")

"Silent sea of pines."—*Coleridge*.

Description.—Leaves in bundles of two, about 2 inches long; cones small, reflexed, adhering tenaciously to the branches, which are often marked by the dead, persistent cones of the previous years; scales in the cone compact, the thickened, quadrangular ends tipped with delicate recurved prickles.

The most abundant of our pines. It usually occurs in large tracts as a dense forest and is found in all of our mountain ranges, especially on the moister slopes and where the winter snows are abundant. It prefers middle elevations, 6,000 to 9,000 feet. When growing in dense tracts it is exceedingly slender for its height and no doubt was formerly the source from which the Indian secured the light, slender poles for his wigwam. Poles 40 to 50 feet in length a man may very easily carry. When the trees are scattering they become less pole-like and attain a diameter of a foot or more. This species has furnished in Wyoming much the larger part of the poles for the miles and miles of fences. The



IX. Lodgepole Pine. *Cones, twig and leaf bundle.*

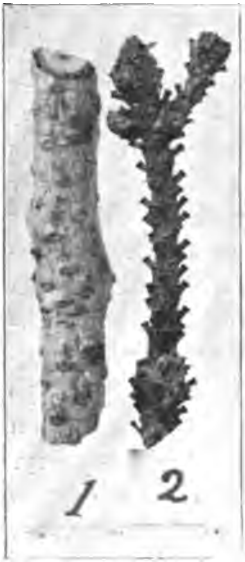
dead poles in a burned district can be prepared with little labor as they are nearly free from branches. Some lumber, railroad ties and much of the "lagging" for mines are obtained from this pine. This species is readily known by its slender habit; its persistent cones, and its paired leaves.

2. SPRUCE.

(*Picea.*)

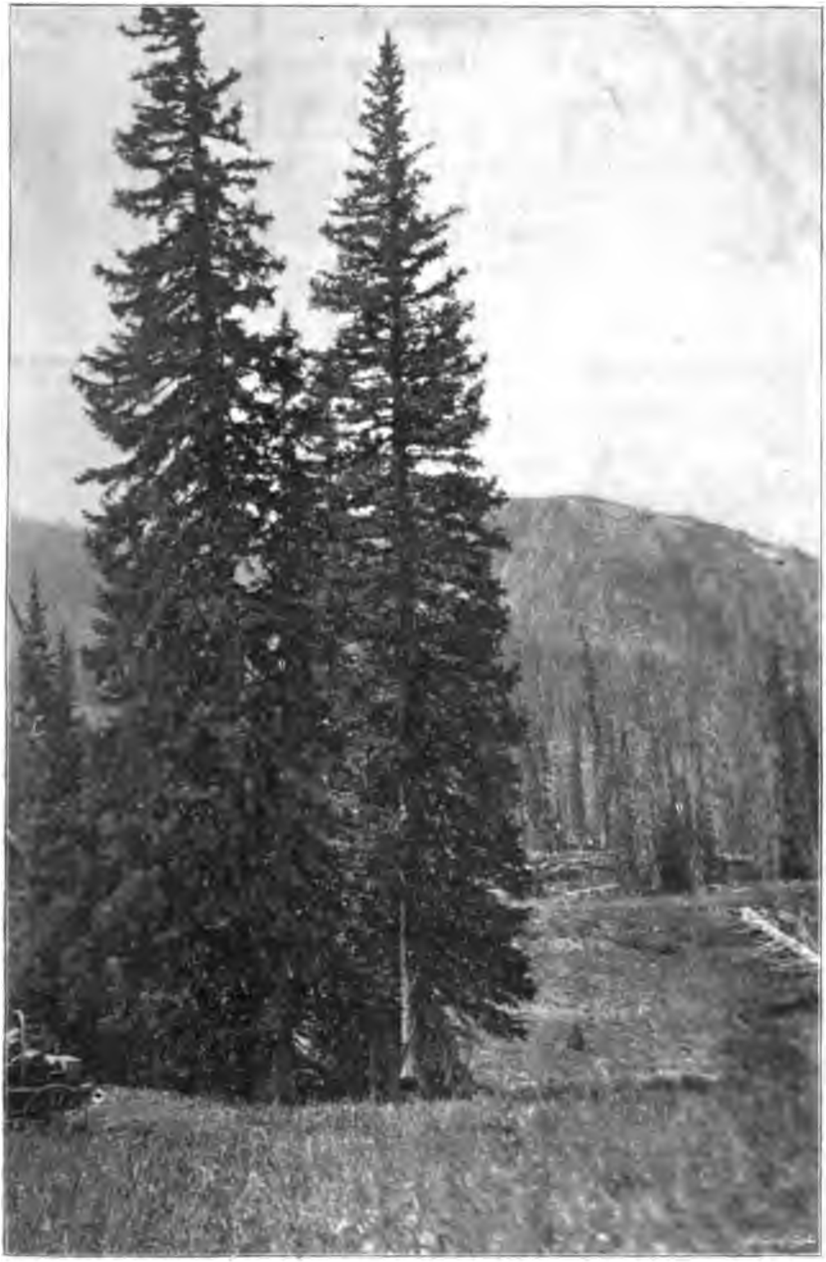
"This is the forest primeval."—*Longfellow.*

There are three trees in the state that are properly known as Spruces. Two of these may be known as ***true*** Spruces (*Picea*) and the third is the Douglas Spruce, which is placed by itself in the following genus (*Pseudotsuga*). All Spruces are at once separated from the Pines by the arrangement of the leaves—in bundles in the Pines, singly in Spruces. They are also easily separated by the cones—heavy with thickened scales in the Pines, light with thin scales in the Spruces.



X. Spruce twigs, showing the manner in which the leaves are detached.
1. Douglas Spruce.
2. The true Spruces.

The *true* Spruces are to be distinguished from the Douglas Spruce by the way in which the leaves are detached from the branchlets. In the former when the leaves fall away the branchlets are rough with the projecting, persistent leaf-bases; in the latter the branchlets are smooth, marked



XI. ENGELMANN SPRUCE. *Characteristic trees. This species often forms a close forest.*

only by the oval scars of the fallen leaves. The accompanying figure will make this plain.

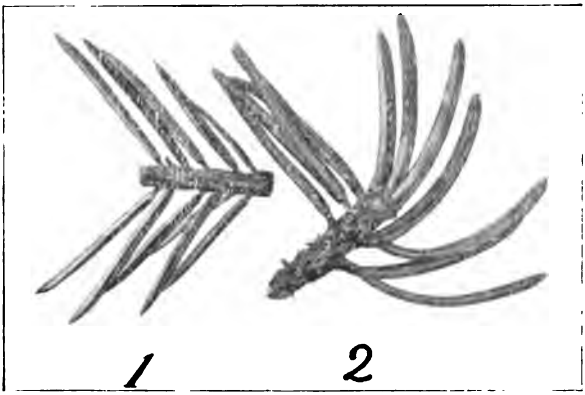
(1) ENGELMANN SPRUCE.

(*Picea Engelmanni* Engelm.)

"Grove nods to grove."—*Pope.*

Description.—Leaves from ½ to 1 inch in length, singly and somewhat uniformly distributed upon the branches, four-angled, abruptly sharp pointed; cones oval or oblong, about 2 inches long and half as thick; scales thin, tough, ovate, with a square-cut tip which is entire or may bear a few small teeth.

This is the most important forest tree in the state. Hundreds of square miles in our higher mountains are completely clothed with it. Though not the largest of our trees, yet it attains in favorable situations a great size, becoming perhaps 100 feet in height and two feet or more in diameter. It is rarely found much below 9,000 feet and from that altitude up to timber-line it is usually the only species. At the upper limit of trees it becomes merely a spreading, prostrate shrub, buried for months beneath the load of the winter snows. These are strikingly different in appearance from the tall, spire-shaped trees on the lower slopes.



XII. Leaves of the true Spruces. *1. Blue. 2. Engelmann.*

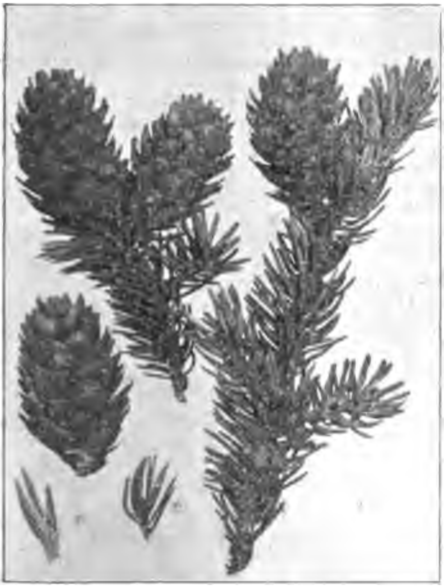
From this species is obtained much of the native lumber that is produced in the state. The wood is firm and elastic and while it is difficult to obtain lumber free from knots, yet since these rarely fall out, it has been found suitable for a large number of purposes.

This is the species that the Forest Reserves are especially designed to protect. These great tracts of subalpine woods hold back the waters of the winter snows, from which the streams are fed late into the summer months.

(2) BLUE SPRUCE.

(*Picea pungens* Engelm.)

"No tree in all the grove but has its charms,
Though each its hue peculiar."—*Cowper.*



XIII. Blue Spruce. *Twigs and cones.*

Description.—Leaves very similar to the preceding, more slender and rigid, more strongly 4-angled and sharper pointed, often with a blue-green (glaucus) color; cones also quite similar (reddish-brown in both), longer and more cylindrical in this, scales very thin and usually with a wavy, irregular edge.

The Blue Spruce, while widely distributed throughout the Rocky Mountains, cannot be said to be abundant. It occurs at intervals throughout our mountains, mostly as scattering individuals or in small clumps. It is found at middle elevations, rarely reaching 9,000 feet, and prefers moist soil. Near streams and on moist slopes it makes a fair-sized tree, but the wood is said to have little value.

It is not readily distinguished from the preceding except by its habitat, its usually smaller size, its cone-shaped habit, i. e., its sharply tapering crown, and its blue-green or silvery foliage.

On account of its handsome appearance it is largely used as an ornamental tree for planting on the home or public grounds.[*] Most of the trees thus used are nursery grown, as they transplant more readily than those removed directly from their mountain habitat.

There is a probability that Wyoming possesses one of the true Fir trees. Though the writer has not found it, he has no reason for thinking that the species that has been reported a few times from our higher mountains is not here. Sometimes such reports arise from mistaken identity, but in this case it will be rather surprising if the presence of the following species is not established:

ALPINE FIR (*Abies lasiocarpa* (Hook.) Nutt.) A slender tree of the higher mountains of the western United States. Its leaves, like those of the Spruce, are borne singly, somewhat in two ranks: the branches are arranged in a succession of whorls: the cones are nearly cylindrical, about 2½ inches long, erect and produced at the sides of the branches: bark thin and pale. If any of the users of this bulletin happen to find this tree, the foregoing statements will aid in distinguishing it from the Spruces, the only trees in this state with which this Fir could be confused. Reports concerning it will be welcome.

3. DOUGLAS SPRUCE.

(*Pseudotsuga taxifolia* (Lam.) Britt.)

"Oh! proudly then the forest kings
Their banners lift o'er vale and mount."—*Edith May*.

Description.—Leaves flattened, with a narrowed, stem-like base, mostly blunt pointed, whitish below, twisting on the base so as to appear comb-like on the branches, ¾ in. to twice that length: cones egg shaped, about 3 inches long and half as thick; three pointed bracts project from among the scales of the cone: bark, in old trees, very thick and furrowed.

This is one of the largest trees of the state and for that matter of the United States. It reaches its maximum size in moister climates, but even here it is a stately tree, often much exceeding a hundred feet in height. It occurs in canons and on rocky slopes up to 10,000 feet, the finest specimens being found near the banks of mountain streamlets. Its wood is hard and durable, making it of much value where heavy timbers are required. Much lumber is made from it and for railroad ties it is considered superior.

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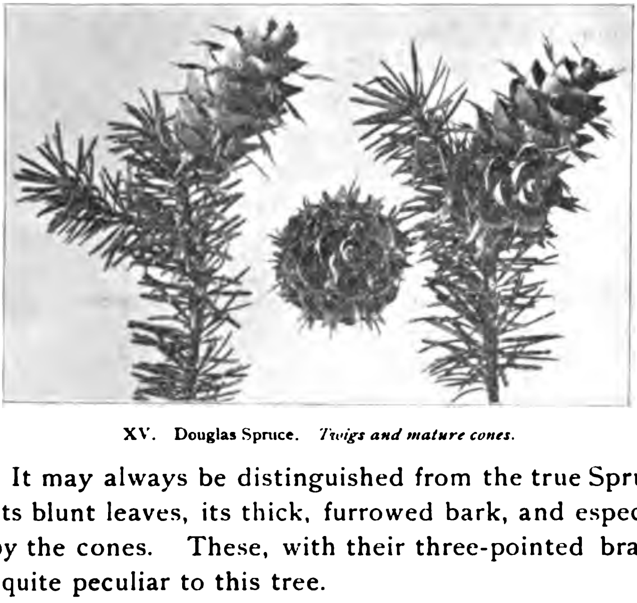
[*] See Bull. 38 of this Station by Prof. B. C. Buffum.



XV. Douglas Spruce. *Twigs and mature cones.*

It may always be distinguished from the true Spruces by its blunt leaves, its thick, furrowed bark, and especially by the cones. These, with their three-pointed bracts, are quite peculiar to this tree.

4. JUNIPERS.

(*Juniperus.*)

"Thus yields the cedar to the axe's edge,
Whose arms gave shelter to the princely eagle."—*Henry VI.*

The members of this genus are often known as *cedars*, but this name properly belongs to another genus, while this group should always be called *Juniper*. Of the twelve tree-like Junipers in the United States, Wyoming has two, both of which have recently been described as new. One of these has been known for years as occurring here, but has been supposed to be the same as the Red Juniper of the eastern states. It was only in 1897 that the distinctions between the two were made out, in part from a series of specimens prepared at the University of Wyoming for Dr. Sargent, Director of Arnold Arboretum. It now bears the name first given below. The other species, the second given below, seems to have been overlooked until named and described by the writer in 1898. This does not mean that it is particularly scarce in its locality but only that, though observed by many, it had been assumed, as with the other, to be one of the well known species.

Though the Junipers are included in the cone-bearers yet the cone will hardly be recognized as such. The scales are small, few and fleshy and form a small globose berry instead of the ordinary cone. This, with the fact that the leaves* are scarcely more than short, fleshy scales, will enable anyone to at once recognize these evergreen trees, our two species of which it will not be hard to separate.

(1) ROCKY MOUNTAIN JUNIPER.

(*Juniperus scopulorum* Sargent).

"Will these moss'd trees,
That have outliv'd the eagle, page thy heels,
And skip when thou point'st out?"—*Shakespeare*.

Description.—Leaves in pairs, very short, nearly clothing the branchlets: berries very numerous, not maturing until the close of the second season, light green when young, when mature blue with a whitish bloom.

This species is found at intervals throughout the

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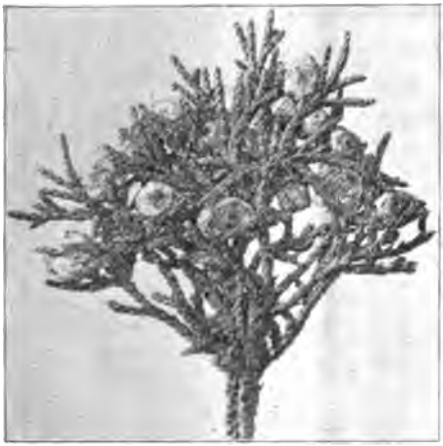
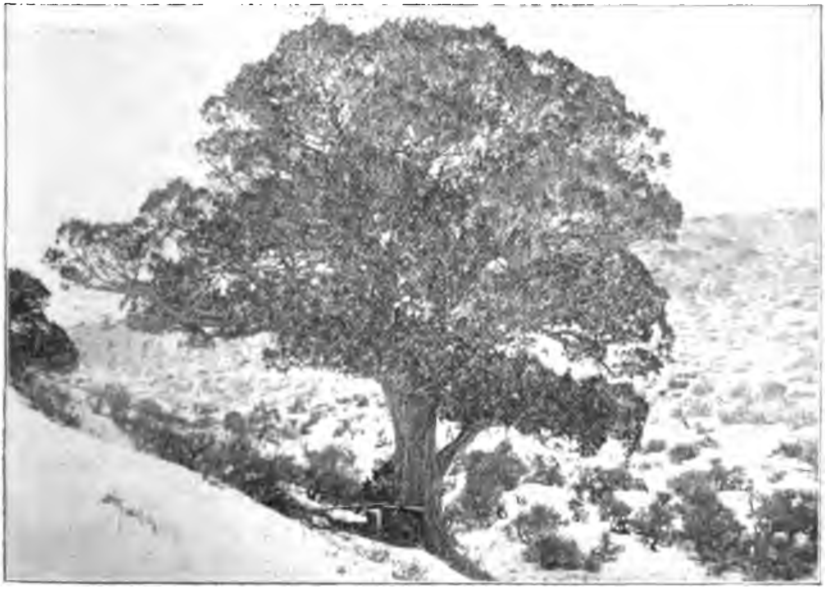
*In very young plants the leaves are usually longer, needle or awl shaped, sometimes ½ inch in length.



XVI. Rocky Mountain Juniper. *The tip of a branch, showing berries.*

state from the southeastern to the northwestern corner. It occurs in canons and on rocky bluffs. Often it is stunted and shrublike but more often a tree with short, thick trunk and rounded top. Sometimes it branches from the base and then resembles in habit the following species. Its wood, though occasion-



XVII. ROCKY MOUNTAIN JUNIPER. *Usual form, but often more shrubby and branched from the base.*

ally used for fuel, is particularly valuable for posts, as it resists decay to a remarkable degree even when in contact with the soil. Its habit, its numerous small, blue berries, which have a whitish bloom, and its slender twigs will serve to separate it from the next.

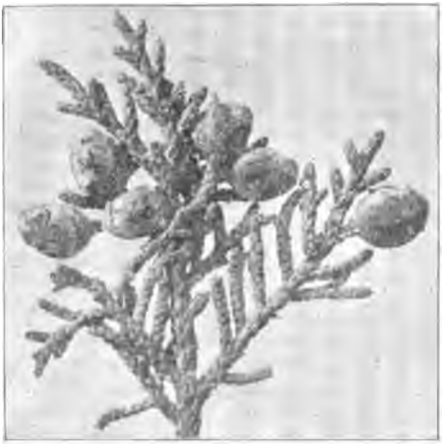
(2) DESERT JUNIPER.

(*Juniperus Knighti* Aven Nelson)

> "The century-living crow,
> Whose birth was in their tops, grew old and died
> Among their branches."—*Bryant.*

Description.—Branched from the base, rarely with a single trunk, usually a rounded, bushy clump of sub-equal trunks and spreading branches, 10 to 30 feet high: leaves three-ranked, thick, about 1-12 inch long; berry blue-green or copper-colored, marked on the surface by more or less projecting points: seed single (rarely two), large, covered by the dry pulp.

So far as the distribution of this tree is known it is confined to the south-central and the southwestern part of the state. It occurs in those desert portions, like the Red Desert, from which all other trees are absent. Even here it occurs only at intervals on the red sandstone hills and bluffs as scattering individuals or sometimes forming considerable thickets. It will be known by its bushy habit, its thick twigs and its large, roughened, copper-colored berries. In the localities where it occurs it furnishes fence posts and fuel.



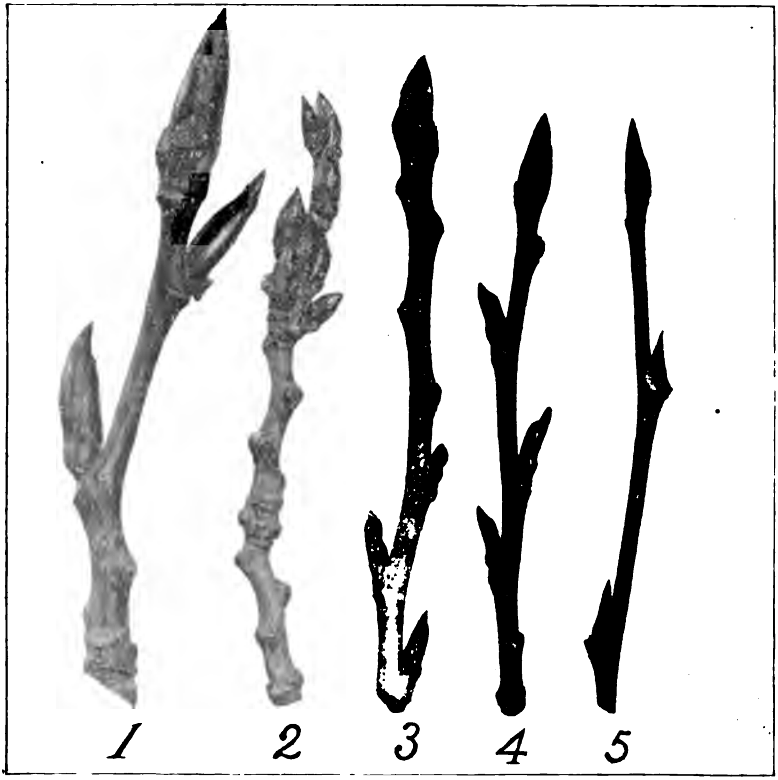
XVIII. Desert Juniper. *The tip of a branch, showing berries.*

XIX. DESERT JUNIPER. *Typical specimens of this species.*

Willow Family.

(*Salicaceæ*)

Although Cottonwoods and Willows seem quite different, yet, botanically, they have many features in common. Both drop their leaves at the end of the growing season, that is they are deciduous. Both have the male and the female flowers on different trees (dioecious). The flowers in both are produced in early spring, before or with the leaves. Male and female flowers are both in slender clusters or tassels known as *aments* or *catkins* (the "pussies" of the children). These are usually drooping in our Cottonwoods but mostly erect in the Willows. The female flower cluster develops into a somewhat similar but more elongated cluster of capsule-like fruits, which are two-celled and contain several small seeds that are furnished with a tuft of fine hairs. When mature these are readily borne for miles by the wind, but only a very small percentage are ever lodged in a suitable place for germination and development.



XX. COTTONWOODS. *Twigs showing characteristic winter buds. 1. Balm of Gilead. 2. Aspen. 3. (Common) Cottonwood. 4. Lanceleaf Cottonwood. 5. Narrowleaf Cottonwood.*

5. COTTONWOOD.

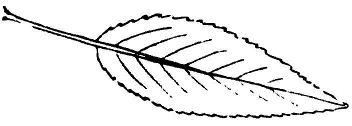
(*Populus*)

" He that plants trees loves others beside himself."

The Cottonwoods need no description as a group. They are known to everyone, but it may not be perfectly clear that the Aspen and the Balm of Gilead are Cottonwoods. In fact we shall not call them by that "common name," but they as well as the other three belong in the genus *Populus*. Our five species are easily known in the summer time by the shapes of the leaves, as shown in the figures accompanying the short descriptions below. Since these are the trees that we must use to a large extent for shade and ornamental planting* in this state, it is desirable that we be able to recognize them in their winter condition also. Transplanting can most safely be done in the spring before the buds open. To assist in recognizing them at that time the accompanying plate, showing a twig and buds of each, will be helpful, as will also a study of the bark character.

(1) NARROWLEAF COTTONWOOD.

(*Populus angustifolia* James)



Description.—Leaves small, oblong or lance-shaped, usually acute at the apex and with rounded base, finely scalloped on the margins: buds small, pointed, dark brown (see Plate XX, Fig. 5): bark thick, coarsely furrowed and dark colored, these characters more pronounced as the tree grows older.

The most abundant of the Cottonwoods (excepting the Aspen) in this state. It becomes in some localities a large tree, sometimes 75 feet high and 3 feet in diameter, though usually it is much smaller. It occurs at intervals on all the larger streams in the state either as a fringe on their borders or in groves quite covering the adjacent low bottom lands. It may always be known by the small, narrow leaves and the dark, thickened, furrowed bark which becomes enormously thickened in the old trees.

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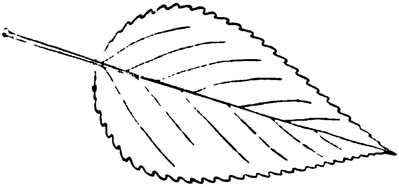
*See Bull. 38 of this Station.

(2) LANCELEAF COTTONWOOD.

(*Populus acuminata* Rydb.)

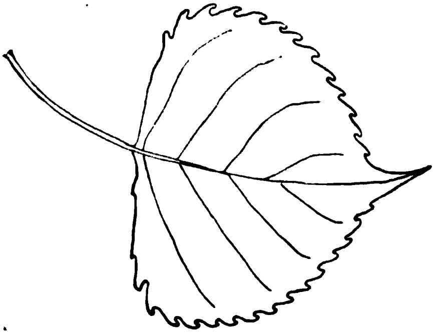


Description.—Leaves broadly lance-shaped or ovate, apex acuminate, finely scalloped on the margins, larger than in the foregoing species, 2 to 3 inches long (on young shoots often more): buds medium sized, light brown (see Plate XX, Fig. 4): twigs slender, light colored: bark in young trees very smooth and almost white, becoming darker and rougher as the trees get older but never so much so as in the preceding species.

Though found native in the state it is far from common and, so far as the writer's observation goes, occurs very sparingly on only a few tributaries of the Platte in the eastern part of the state. That it occurs elsewhere within our borders is, however, quite probable. It attains nearly as great a size as the preceding but is a smoother, handsomer tree at all times. It makes a more rapid growth, is a trifle less hardy but is used largely for planting—mostly from nursery stock.

(3) COTTONWOOD.

(*Populus deltoides* Marsh.)



Description.—Leaves broad, deltoid-ovate, the apex abruptly pointed, the base nearly truncate, rather coarsely scalloped or toothed on the margin: buds larger than in the preceding (see Plate XX, Fig 3): the youngest branchlets angled: bark grayish, becoming rough and irregularly furrowed as the tree gets older.

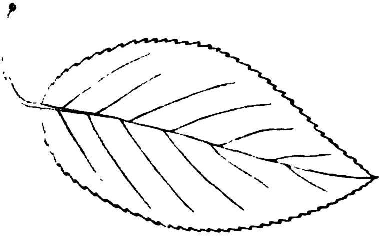
This is the (common) Cottonwood of

the eastern and central United States. Throughout that region it is very abundant but it just comes into our range on the eastern border of the state. On the Platte and its tributaries and in Crook and Weston counties it is known to occur. It is the largest of the Cottonwoods and may easily be known by its leaves and the "necklace-like" fruits as well as by the bark which is roughened by oblique furrows, and is nearly uniform in color throughout.

Like the preceding it is used to some extent for fuel and other domestic purposes but the wood is soft and weak and not very highly valued.

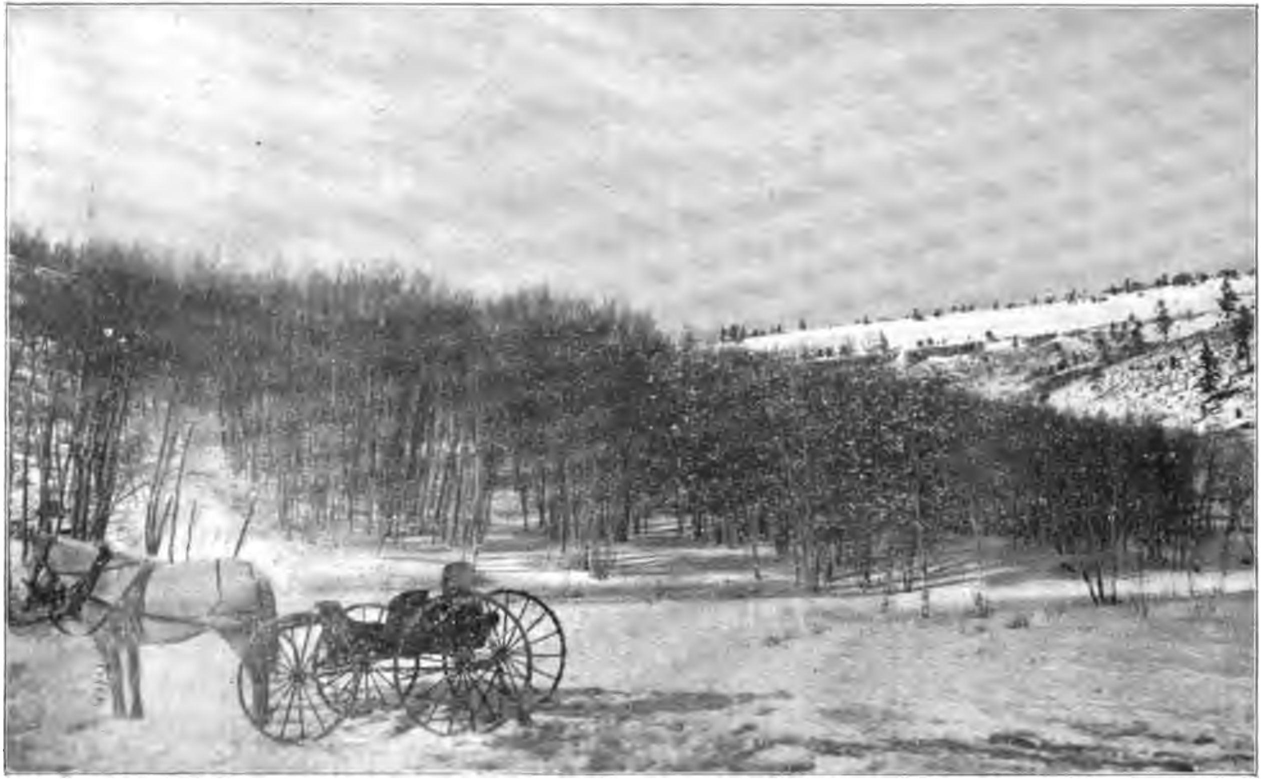
(4) BALM OF GILEAD.

(*Populus balsamifera* Linn.)



Description.—Leaves ovate, tapering gradually to the acute apex, smooth and green above, whitish beneath, finely scalloped on the margins: buds large, coated with resinous, glutinous gum (see Plate XX, Fig. 1): bark smooth on young trees, somewhat roughened on the old, darker in color than in the Lanceleaf Cottonwood which also has nearly smooth bark.

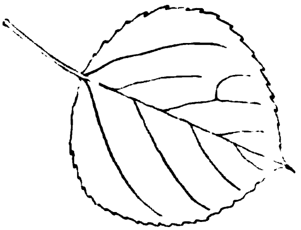
This species is of rather rare occurence in Wyoming. Its range is eastward and northward in the United States and Canada where, in favorable situations, it attains a large size. It seeks sheltered localities on the banks of small lakes and streams. It may be expected in such situations in all parts of this state, though it is never found in abundance—usually scattering trees or small groves only. With us it has little economic importance except as a shade or ornamental tree. Its large resinous buds, leaves shiny above and whitish beneath, and bark comparatively smooth will enable anyone to know this tree.



XXI. AN ASPEN GROVE. *Characteristic location among the hills.*

(5) ASPEN.

(*Populus tremuloides* Michx.)



Description.—Leaves small, broadly ovate or rounded, abruptly short pointed, finely toothed on the margins, leafstalks flattened latterally causing them to tremble in the slightest breeze: buds short and thickened (see Plate XX, Fig. 2): somewhat crowded at the ends of the twigs: bark smooth except in very old trees.

Found in abundance in those parts of the state where hills or mountains abound. It occurs as thickets or groves on the slopes where snowdrifts form and on the banks of mountain streams. Our illustration shows a characteristic location and a typical Aspen grove. The trees are usually small but in very favorable situations may attain a height of 50 feet or more.

The long, slender, pole-like trunks are used more or less for fencing, and as fuel are not to be despised. Transplanted from the grove and set out singly they grow but slowly and never form shapely trees.

6. WILLOW.

(*Salix*)

Perhaps no other state in the United States possesses so many different kinds of willows as Wyoming. Mr. M. S. Bebb (now deceased), the greatest authority on willows in recent times, in a letter to the writer a few years since emphasized "Willow State" as a suitable name for Wyoming. In spite of the large number of species found within our borders we have very few that attain tree-like size. Most of them are mere shrubs, forming great thickets on the borders of our mountain brooks and swamps and fringes on the banks of the larger streams. The few merely named below do, however, attain the stature of small trees. No attempt will be made to characterize these as it would require more space and fuller botanical descriptions than this bulletin contemplates.* Everyone knows a willow, knows where willows are to be sought and knows, too, something of their uses. The following are the species that may be included among the trees of the state:

(1) ALMONDLEAF WILLOW.

(*Salix amygdaloides* Anders.)

One of our largest and most widely distributed tree-like willows. It is generally spoken of simply as the "common willow."

(2) WESTERN BLACK WILLOW.

(*Salix lasiandra* Benth.)

The Wyoming form of this willow is considered only a variety (var. *caudata*) of the species as written above. It ranks with the preceding in size and is widely distribted in the state.

(3) BEBB WILLOW.

(*Salix Bebbiana* Sargent)

Though never large it is decidedly tree-like on account of its usually single trunk and rounded bushy top.

It seems doubtful whether any of the other numerous species attain such a size as to be called trees.

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*Possibly sometime in the future it may seem of sufficient importance to issue a special bulletin on our Willows and their uses. The entire list and the means of recognizing them may then be given.

Birch Family.

(*Betulaceæ*)

This family is represented by three Birches and one Alder. One of the Birches (*Betula glandulosa* Michx.) is only a small shrub occurring in swales in the mountains, so need not be mentioned further in this bulletin. None of the members of this family become very large in Wyoming, but they are to be recognized as true trees. No lengthy description is necessary, for there are no trees in the state with which they can be confused. As in the Willow Family, the flowers are borne in separate clusters, but in this on the same plant, while in the Willows they are on separate plants. The male flowers are in slender, drooping clusters, while the female form shorter, thicker and erect aments. The numerous fruits in the cluster, when ripe, are small, flattened, one-seeded nutlets with a small, thin wing at either side.

7. BIRCH.

(*Betula*)

Our Birches are slender trees with slender, limber branches and rather small leaves; the seed-like nutlets distinctly winged. The two species are easily separated by the bark alone.

(1) PAPER BIRCH.

(*Betula papyrifera* Marsh)

Description.—Bark white, smooth, on young branches often with numerous dots, peeling readily into thin, paper-like layers, hence the name: leaves ovate, small, toothed on the margins.

This species in northern and eastern America becomes quite a large tree. Since its bark was the source of the Indian's canoe it is sometimes called the "canoe birch." Since it has also often furnished the material upon which letters were written, it has always been of much interest. It is very rare in Wyoming, probably occurring only in the northeastern part, in the Black Hills. Here fine specimens of it are not rare, though they seldom attain any great size.

XXII. Paper Birch. *Leaf and fruit cluster (ament).*

(2) WESTERN BIRCH.

(*Betula occidentalis* Hook.)

Description.—Bark smooth, dark or bronze-colored: branches resin dotted: leaves ovate or sometimes nearly round, sharply toothed, rather small and thin: the very small, seed-like nut with broad wings.

This birch occurs on many of our mountain streams, usually as a mere fringe on the banks but occasionally as small thickets. It attains a height of 25 to 40 feet and furnishes slender poles often used for fencing as well as for fuel. It need never be confused with the preceding, but is less readily distinguished from the following.

8. ALDER.

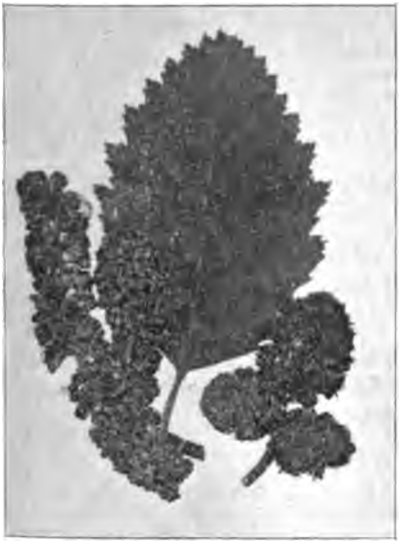
(*Alnus*)

This genus is represented by one species only, and since it is of small economic value it may be treated briefly.

(1) PAPERLEAF ALDER.

(*Alnus tenuifolia* Nutt.)

Description.—Leaves rather large, sharply double-toothed: flowers in clustered aments, developing during the summer preceding the season in which they open and hanging naked upon the branches during the winter, opening in the spring before the leaves develop: seed-like nutlet slightly margined but scarcely winged.



XXIII. Paperleaf Alder. *Leaf, male flower cluster (left) and fruiting cluster.*

This is little more than a large shrub, but since it occurs so extensively throughout the state and lends itself so readily to transplanting it seems well to include it. It usually forms clumps of several or numerous stems from the root and grows as an overhanging fringe on the banks of mountain streamlets. Its habit of growth and the presence in winter of the naked flower clusters will help to separate it from the Western Birch, the only species with which it can be confused. It has some fuel value and often constitutes natural windbreaks that are of service to ranch homes and to stock on the range. It can be used effectively for ornamenting the home grounds.

Beech Family.

(Fagaceæ)

Because of similar botanical characteristics the Oak genus (*Quercus*) is placed in the above family. Since for our present purposes we are concerned with a single species of Oak, we need not consume space in describing this family. but may pass at once to the genus.

9. OAK.

(*Quercus*)

> "The monarch oak, the patriarch of the trees,
> Shoots rising up, and spreads by slow degrees:
> Three centuries he grows, and three he stays
> Supreme in state, and in three more decays."—*Dryden.*

The Oaks belong to that group of trees that are often spoken of as "hardwoods." While the quality of the wood in the several species differs greatly, yet all furnish timber of much value. As sources of lumber for furniture, implements, machinery and for all sorts of timbers where great strength is required this group holds an important place.

(1) BUR OAK.

(*Quercus macrocarpa* Michx.)

XXIV. Bur Oak. *Acorns and cups.*

Description.—Leaves obovate, deeply lobed, the lobes rounded, pale and slightly downy beneath: nut at first wholly enclosed in the cup, becoming rather large and at maturity usually less than half enclosed: the scales of the cup conspicuous.

This species has a wide range in North America and in favorable situations becomes a very large tree. Like most oaks, it thrives only at low altitudes. On that account it is something of a surprise to find it in Wyoming at all. It is, however, quite abundant among the hills in the lowest portions of Crook County. In such situations it is usually much reduced in size, but here in some places it is not only well represented but many specimens become fine trees 2 to 3 feet in diameter. It is one of the valuable timber trees of that county.

Maple Family.

(*Aceraceæ*)

The Maple Family has three representatives, all of them small, the Box Elder being the largest of the three. The Silver, or Soft, Maple, so largely used as a shade tree in the states lying to the east of this, does not occur here and will not endure the climate of many parts of this state. The species that do occur are all much hardier, but are shrubby in habit and less well adapted for transplanting.

10. MAPLE.

(*Acer*)

This is the only genus in this family in North America. All its members are trees or shrubs with watery or sweetish sap, the seed-like fruit in pairs and conspicuously winged. Our species are as follows:

(1) DWARF MAPLE.

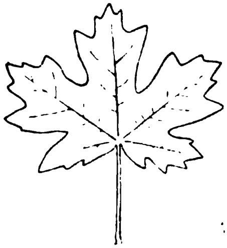
(*Acer glabrum* Torr.)

Description.—Leaves 1 to 2 inches long, smooth or nearly so on both sides, lobed, the lobes acute and sharply toothed: the winged seeds about 1 inch long.

This species is common in the foothills and the more broken areas of the state. It prefers canons and canon sides where it is hardly more than a shrub, growing in clumps of larger or smaller size. More rarely it becomes a small tree 20 to 30 feet high. It may always be recognized by its paired (opposite) buds, sharply lobed leaves, light colored bark and the paired wing-fruits. A clump or two of it on the home grounds would add much to the interest of the surroundings.

(2) LARGE-TOOTH MAPLE.

(*Acer grandidentatum* Nutt.)

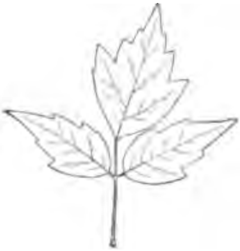


Description.—Leaves 3-lobed, the notches rounded and the lobes wavy-toothed, larger than in the preceding: seeds as in the foregoing but slightly smaller and with narrower wing.

This Maple belongs west of our range but it occurs sparsely in the southwestern part of the state and possibly along our whole western border. It is nearly related to the Sugar Maple but being small and scattering its sap is not utilized. In rare instances the trees become 35 to 40 feet high and a foot in diameter. The sketch of the leaf shows the characters that easily separate this leaf from that of the preceding. With leaf and seeds (even young ones) in hand there can be no mistaking this for any of our other trees.

(3) BOX ELDER.

(*Acer negundo* Linn.)



Description.—Leaves compound, i. e. 3 to 5 leaflets (as shown in figure) on each leafstalk, pubescent when young, smooth when old, few toothed or rarely somewhat lobed: wing-fruits paired and very similar to the preceding Maples but broader and finely veined.

We do not always think of the Box Elder as a Maple but its fruit and floral characters show that it is very closely related to the others. It is fairly plentiful throughout the entire eastern part of the state along the streams. Its habit is always tree-like but it rarely attains a great size—25 to 40 feet in height and a foot in diameter being probably the maximum. It is hardy and may be readily transplanted though in higher portions of the state it makes slow growth and may need some protection. Its fruits, its leaves and the slender, drooping clusters of greenish flowers make it easily recognizable.

Olive Family.

(*Oleaceæ.*)

This family contains about a score of genera only a few of which belong to North America. Of these the common Lilac (*Syringa*) and the Ash (*Fraxinus*) are the best known. Since the members of this family differ greatly among themselves, our species only need be considered.

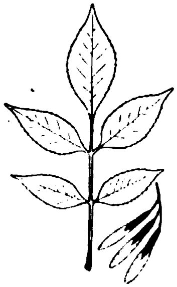
11. ASH.

(*Fraxinus.*)

Of the dozen or more species in the United States, one (possibly two) occurs in Wyoming. All are trees and some of them attain a great size, furnishing timber of much value. They are easily known by the compound leaves and the winged fruits as shown in the figure below. The fruits are borne in clusters and do not differ materially except in the relative size of the wing and the body of the seed.

(1) GREEN ASH.*

(*Fraxinus lanceolatus* Borkh.)



Description.—Leaflets 5–9, finely toothed on the margins, long pointed, green on both sides: male and female flowers on different trees, in a close cluster, appearing with or before the leaves: fruits about 1¼ inches long.

This species appears but sparingly in this state, only so far as known on some of the streams in the eastern part, though probably it occurs northward in the lowest portions of the state as well. Its wood is valuable but the trees with us are too small and scattering to have any economic importance except as it may be used as a shade or ornamental tree.

Plum Family.

(*Drupaceæ.*)

This family is represented by the common Wild Plum and one species of Choke Cherry. As is well known these trees are all small, all have a fleshy fruit with a single stone-like seed.

PLUM AND CHERRY.

(*Prunus.*)

Here belong Plums and Cherries of all kinds, too well known to need any description. Our species are as follows:

---

*There is a possibility that in the Black Hills of Crook County some specimens of the Red Ash (*Fraxinus Pennsylvanica* Marsh) may be found. Though it rather closely resembles the Green Ash yet it may be known by the leaves being pale and soft, or velvety, hairy below and the body of the seed being about as long as the wing.

(1) WILD PLUM.

(*Prunus Americana* Marsh)

Description.—Leaves ovate, pointed, sharply toothed, smooth when old: fruit globose, red or yellowish; seed flattened.

This small tree occurs with more or less frequency in the northeastern counties and yields occasionally a considerable amount of its pleasantly acid fruit. It is well worthy of cultivation for not only does it yield better fruit and more of it, when the tree is cared for, but it is at the same time a desirable addition to the trees of the home grounds, because of its wealth of white flowers.

(2) WESTERN CHOKE CHERRY.

(*Prunus demissa* (Nutt) Walp.)

Description.—Leaves ovate, acute, finely serrate: the white flowers in dense, cylindrical clusters: fruit when ripe nearly black.

In most localities this is only a small shrub but in very favorable situations it becomes a tree 20 or more feet high. The handsome, clustered flowers and fruit ought to give it more extended use in ornamenting the home grounds. From the fruit may be made a superior jelly, especially when mixed with other native fruits such as the Barberry or Buffalo Berry.

Apple Family.

(*Pomaceæ*)

Of the several genera in this family we need to notice but two. These in common with the others have a fleshy fruit formed by the thickened calyx tube which encloses the seed vessels.

13. HAW.

(*Cratægus*)

> "Gives not the hawthorn bush a sweeter shade
> To shepherds, looking on their silly sheep,
> Than doth a rich embroidered canopy
> To kings, that fear their subjects treachery."—*Henry VI.*

The Haw, or Hawthorn as it is often called, includes several species of small trees, mostly with short, well formed trunks, a rounded bushy top and more or less thorny or spiny branches. The small, edible, apple-like fruit with its large, bony seeds well distinguishes this genus.

(1) BLACK HAW.

(*Cratægus Douglasii rivularis* Sargent)

XXV.—Black Haw.

Description.—Leaves narrowly to broadly ovate, irregularly sharply toothed, mostly green and smooth above, paler beneath: fruit black when ripe, about ⅜ of an inch in diameter: thorns stout, an inch (more or less) in length.

A small tree of fine appearance, well worthy of cultivation. Its wealth of flowers in May or June, according to altitude, and its abundant clusters of fruit which remain on the tree for a long time make it an object of much interest. There are two forms of this in the state which differ slightly in leaf form but prbably in no essential character. It occurs on most of the larger streams of the state, and may be at once separated from the next by its black fruit.

(2) LONGSPINE HAW.

(*Crataegus macracantha* (Lindl.) Loud.)

Description.—Leaves sharply double-toothed, dark green, smooth above, slightly hairy on the veins beneath: calyx glandular: fruit globose, about ⅜ of an inch in diameter, red when ripe.

This species is more shrub-like and with more straggling branches but it is equally desirable for home planting. Its wealth of white blossoms and its red fruit make it an attractive shrub or tree. While the fruit has no great value yet of the two this is probably superior to that of the preceding. This species is not known to the writer as occurring in this state outside of Crook county but it probably exists elsewhere also.

14. SERVICEBERRY.

(*Amelanchier*)

> "The shad-bush, white with flowers,
> Brightened the glens."—*Bryant.*

This is the name given to a few species of shrubs and small trees belonging mostly to North America, and variously known as Juneberry, 'sarvice' berry, and shad-bush. It generally occurs in broken, hilly country and produces an abundance of edible, berry-like fruits. The species given below is common throughout the Rockies and is the only one that becomes a tree in this state, and that rarely, though it is abundant as a shrub.

(1) WESTERN SERVICEBERRY.

(*Amelanchier alnifolia* Nutt.)

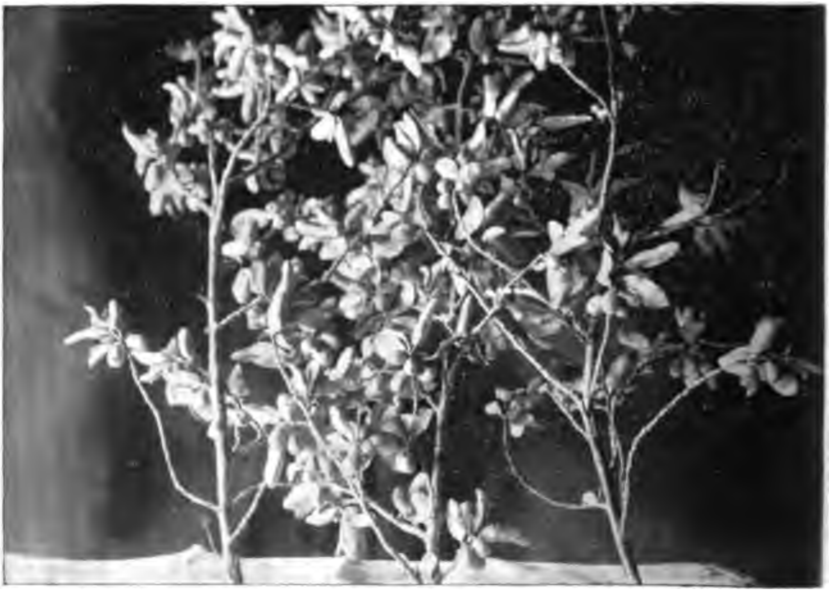
Description.—Leaves thick, rounded or elliptic, toothed around the upper half only: flowers in clusters (racemes), white, appearing before or with the leaves: fruit purple or nearly black when mature, ¼ to ⅓ inches in diameter.

Occurring among the hills throughout the state, especially along the streams at middle altitudes. The fruit is palatable, particularly if fresh, though it is used to a considerable extent as sauce and in pies. Ripening in July or August, according to altitude.

Oleaster Family.

(*Elæagnaceæ*).

Two tree-like shrubs are to be mentioned under this family because of their ornamental value. Both have silvery foliage, due to minute scales which cover the surface. both have one-seeded fruits.



XXVI. **SILVER BERRY.** *Twigs, leaves and silvery fruit.*

15. SILVER BERRY.

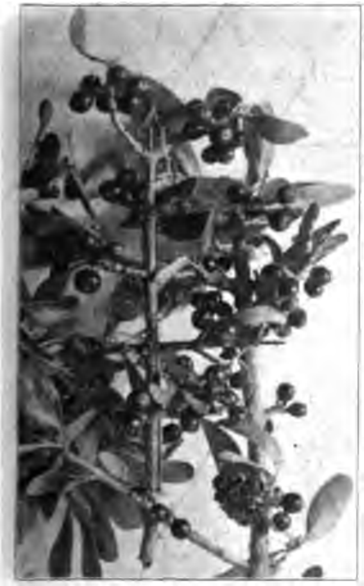
(*Elæagnus argentea* Pursh.)

Description.—Leaves elliptic, silvery-scurfy as are also the twigs, flowers and fruit: fruit oval, ½ inch in diameter, dry, mealy: seed large, stone-like: branches without spines.

This beautiful shrub occurs in the northern and western parts of the state, mostly on the bluffs and ridges adjacent to streams. It is not common but may have a wider distribution than has yet been shown. Its perfectly matched leaves and fruit, as to color, makes it of much interest.

16. BUFFALO BERRY.

(*Lepargyrea argentea* (Nutt.) Greene)



XXVII.—Buffalo Berry. *Twigs in fruit.*

Description.—Leaves oblong, obtuse, silvery on both sides: fruit a small, oval berry, bright scarlet when ripe, highly acid, edible: branches spiny.

This well known shrub occurs in many parts of the state, on the stream banks. Its silvery leaves and its profusion of small, scarlet berries give it a conspicuous beauty all its own. The fruits are largely gathered for the excellent jams and jellies that can be made from them. Screens and hedges of this useful shrub can be used to advantage by the landscape gardener on either home or public grounds.

XXVII. BUFFALO BERRY. *A natural hedge of well grown shrubs.*

Is it too much to hope that this bulletin may be one of the factors (however small) which shall arouse in our people a keener appreciation of the value of our forests, a more loyal support of all measures looking to their preservation, a greater interest in the beautifying of our homes and public grounds with trees and shrubbery and a more cheerful willingness to work and plant, that those who come after us may have a more wholesome and happier place in which to live? As we interest ourselves in these directions, the love of nature will grow upon us and we too shall say,

> "And this our life, exempt from public haunt,
> Finds tongues in trees, books in running brooks,
> Sermons in stones, and good in every thing."—*Shakespeare.*

UNIVERSITY OF WYOMING.

Agricultural College Department.

WYOMING EXPERIMENT STATION,

LARAMIE, WYOMING.

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JULY, 1898.

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May 1, 1891, to June 30, 1898.

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REPORTS NOS. 1 TO 8, INCLUSIVE.

INDEXED BY GRACE RAYMOND HEBARD.

Bulletin No. 1—May, 1891. The Organization and Proposed Work of the Station. D. McLaren, Director.

“ No. 2—August, 1891. Plant Lice. F. J. Niswander, Entomologist.

“ No. 3—November, 1891. The Sugar Beet in Wyoming. D. McLaren, Agriculturist, and E. E. Slosson, Chemist.

“ No. 4—December, 1891. Meteorology for 1891. B. C. Buffum, Meteorologist.

FIRST ANNUAL REPORT, 1891.

General Statement Regarding Station Work, with Bulletins Nos. 1 to 4, inclusive. D. McLaren, Director.

Bulletin No. 5—February, 1892. Best Varieties and Breeds for Wyoming. D. McLaren, Agriculturist, and B. C. Buffum, Horticulturist.

“ No. 6—May, 1892. Soils of the Agricultural Experiment Farms. Relation of Geology and Chemistry of Soils to Agriculture, J. D. Conley, Geologist. Anaylsis of the Soils of the Wyoming Experiment Station Farms; E. E. Slosson, Chemist.

“ No. 7—July, 1892. Insecticides. F. J. Niswander, Entomologist.

“ No. 8—October, 1892. Irrigation and Duty of Water. B. C. Buffum, Horticulturist.

Bulletin No. 9—December, 1892. Sugar Beets in Wyoming in 1892. E. E. Slosson, Chemist.

" No. 10—December, 1892. Meteorology of Wyoming in 1892. B. C. Buffum, Meteorologist.

SECOND ANNUAL REPORT, 1892.

General statement with Bulletins Ncs. 5 to 10. A. A. Johnson, Director.

Bulletin No. 11—February, 1893. Crop reports for 1892. A. A. Johnson, Director, and F. J. Niswander, Superintendent Laramie Farm.

" No. 12—April, 1893. Ground Squirrels (Gophers). F. J. Niswander, Entomologist.

" No. 13—July, 1893. The Feeding and Management of Cattle. W. A. Henry, Ph. D., University of Wisconsin. (Reprint by Permission).

" No. 14—October, 1893. Geology of the Wyoming Experiment Farms, and Notes on the Mineral Resources of the State. W. C. Knight.

" No. 15—December, 1893. The Winter-Killing of Trees and Shrubs. Aven Nelson, Botanist.

" No. 16—December, 1893. Grasses and Forage Plants. B. C. Buffum, Horticulturist.

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Bulletin No. 17—March, 1894. I. Crop Report for 1893. II. Cost and Profit of Growing Wheat. III. Sugar Beets. IIII. Garden Vegetables and Tobacco. V. Meteorology for 1893. B. C. Buffum, Horticulturist, and E. E. Slosson, Chemist.

" No. 18—June, 1894. I. Reclamation of Arid Lands. II. The Harvey Water Motor. A. A. Johnson, Director.

" No. 19—September, 1894. Squirrel Tail Grass (Fox-Tail); One of the Stock Pests of Wyoming. Aven Nelson, Botanist.

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Bulletin No. 22—April, 1895. I. Onions. II. Crop Reports, 1894. 1, Potatoes; 2, Turnips and Other Root Crops; 3, Grasses and Forage Plants; 4, Cereals; 5, Other Crops. III. Cost and Profit of Growing Wheat. IIII. Small Fruits at Laramie. B. C. Buffum, Agriculturist and Horticulturist.

" No. 23—May, 1895. Notes on Climate. J. D. Conley, Meteorologist.

" No. 24—August, 1895. Water Analyses. E. E. Slosson, Chemist.

" No. 25—November, 1895. Results of Three Years' Experiments in Cost and Profit of Growing Wheat. B. C. Buffum, Agriculturist.

" No. 26—December, 1895. Garden Peas. B. C. Buffum, Agriculturist and Horticulturist.

FIFTH ANNUAL REPORT, 1895.

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Bulletin No. 27—March, 1896. Meteorology for 1895, and Notes on Climate from 1891 to 1896. J. D. Conley, Meteorologist.

" No. 28—May, 1896. First Report on the Flora of Wyoming. Aven Nelson, Botanist.

" No. 29—July, 1896. Alkali. B. C. Buffum, Agriculturist.

" No. 30—September, 1896. Stock Feeding Experiments at Lander. B. C. Buffum, Agriculturist.

" No. 31—December, 1896. The Worst Weeds of Wyoming and Suggested Weed Legislation. Aven Nelson, Botanist.

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" No. 33—June, 1897. The Composition of Prepared Cereal Foods. E. E. Slosson, Chemist.

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" No. 35—December, 1897. Mechanical Analyses and Water Content of Wyoming Soils C. B. Rigdaway, Physicist.

" No. 36—April, 1898. Wyoming Sugar Beets. E. E. Slosson, Chemist.

" No. 37—June, 1898. Stooling of Grains. B. C. Buffum, Agriculturist.

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TENTH ANNUAL REPORT

OF THE

AGRICULTURAL COLLEGE

OF THE

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AND OF THE

WYOMING

AGRICULTURAL EXPERIMENT STATION

FOR THE FISCAL YEAR ENDING JUNE 30, 1900

LARAMIE, WYOMING:
CHAPLIN, SPAFFORD & MATHISON, PRINTERS.
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*Resigned to accept chair of agriculture at Colorado Agricultural College, Fort Collins, Colorado. Prof. Luther Foster, M. S. A., of Logan, Utah, elected to fill vacancy.

TENTH ANNUAL REPORT

. . . OF THE . . .

Agricultural College of the University of Wyoming.

I hereby submit the tenth annual report of the College of Agriculture of Wyoming, in compliance with enactment of Congress. Following this report is a paper written by our chemist, Professor Edwin E. Slosson, and Mr. R. B. Moudy, of last year's senior class, on The Cement Plaster of Laramie. This will be found an interesting monograph on a growing home industry.

INCEPTION OF THE COLLEGE.

The first president of the university of Wyoming, when constructing the various courses of the institution, in accordance with the act of incorporation, planned for distinct schools of agriculture and mechanic arts. These departments did not obtain much growth until 1891.

On the 10th of January of that year they were organized into separate colleges by an act of the legislature of Wyoming, which vested the control of the appropriations from the Morrill Act of Congress in the Board of Trustees of the State university. The Morrill Act, approved August 30, 1890, was intended to grant an endowment for agricultural and mechanical colleges in addition to that obtained by a land grant on July 2, 1862.

PRESENT MANAGEMENT AND COURSE.

The Board of Trustees, whose names appear on a preceding page, has not changed since the last report.

The Biological Laboratory is provided with sinks, gas water, excellent compound and dissecting microscopes, microtomes, turntables, waterbaths, charts, models, photographic apparatus, and the necessary appliances for bacteriological work.

The Machine Shops are run as nearly as possible to correspond with actual manufacturing establishments. In the wood room each student has his own chest of tools for bench work and has the use of turning lathes, pattern maker's trimmer, mortising machine, pony planer, short jointer, boring machine, band saw, scroll saw, variety wood worker, and circular saw with two cross cut and two rip saws. The iron room is provided with a 24 inch x 24 inch x 6 foot planer, a 25 inch back geared power feed drill press, a universal milling machine, a 14 inch x 6 foot engine lathe, a 16 inch x 6 foot engine lathe, a power back saw, a twist drill grinder, a power pipe-threading machine, a 14 inch sensitive drill, and an emery grinder with two 14 inch wheels. The foundry contains a Whiting cupola, 32 inch outside diameter lined down to a 23 inch, which has a capacity of melting from 1,000 to 2,000 pounds of iron an hour. It is also provided with six 50 pound ladles, one 200 pound ladle, core oven, flasks, riddles, bellows, and all tools necessary to operate a first-class foundry. There are also complete sets of piping tools for steam fitting, and a forge for sharpening and tempering. Advanced classes have the use of an American Thompson Indicator and Arndt's Econometer with which to take indicator cards and test the efficiency of boilers.

MUSEUM.

A good start has been made on an Agricultural Museum; but until we have more room little further can be done in this direction. The cases are large and built of substantial oak. They contain a collection of specimens of the cultivated crops and wild grasses of Wyoming. With the collection of crops are the seeds of each in neat exhibit bottles. The exhibit also includes some rare seeds from Africa, Japan, and other foreign countries. The cereals and forage crops raised on the Laramie experiment farm occupy one case. They are arranged in an artistic manner and contain heads of grain that for size and perfection of shape are rarely surpassed. The exhibition of wild grasses consists of a portion of those sent to the World's Fair in 1893, which received the award of a medal and diploma. The fruits of our state are not as yet represented, but some work has been done in reproducing the fruit in wax, thus making it possible to keep them on exhibition in permanent form.

The collection contained in this museum is instructive to the student and gives the stranger a good idea of what Wyoming is capable of in agriculture.

ROCKY MOUNTAIN HERBARIUM.

We have by all odds the largest and most representative collection of Rocky mountain plants to be found anywhere. On this account we have seen fit to give the name of Rocky Mountain Herbarium to our collection.

The Herbarium now contains about 22,000 specimens. It is a fair working collection of the plants of the Western United States, being rich in those of the Rocky Mountains, and especially of Wyoming. A steady growth is maintained, collections of much value being added each year. It represents the flora of Wyoming so far as known and is becoming of more and more interest to students who desire to make a special study of the plants of this range, especially so since it contains the types of many new species recently described. The Herbarium is open to University students and others whose previous training is such as to enable them to profit by its use.

NEW BUILDING.

A new building, which will be known as the Hall of Science, is now in course of erection. Only the central or main part will be erected at present; for the building has been so a thorough grounding in the fundamental facts, the student is expected to observe the social phenomena about him and to study the various problems in an independent manner. Inasmuch as sociology is a science of recent birth, and its theories are constantly expanding, much of the class-work consists of lectures and theses. The following subjects are offered:

I. *Principles of Sociology.* Small and Vincent; Giddings; Kidd's Social Evolution. Lectures; theses; debates. [Elective for agricultural seniors.]

II. *Social Problems.* Study of crime, suicide, insanity, pauperism, charities, intemperance, socialism, education, etc. Discussions; theses. [Elective for agricultural seniors who have taken I and Philosophy IV.]

III. *Social Philosophy.* Lectures on social theories, old and new, and on the aims of society. Discussions; theses. [Elective for agricultural seniors who have taken I and II.]

PHILOSOPHY.

The work of this department is intended to furnish an acquaintance with philosophic thought, to afford a training in the methods of investigating philosophic phenomena, and to imbue the student with the latest methods of education. Special attention is given to physiological psychology. The work in this subject is illustrated by charts and models of the brain and sense organs and by the introduction of various experiments. In teaching logic more time than formerly is given to inductive reasoning, as a perfect knowledge of this form is especially helpful to scientific students and to those intending to do research work in philosophy.

I. *Psychology, Introductory.* James's Briefer Psychology, or Titchener's Outlines of Psychology. Collateral readings. The purpose of this course is to give the student insight into the principal psychological conceptions and methods, and practice in simple psychological experimentation. [Required of agricultural juniors.]

II. *Psychology, Advanced.* Investigation of special topics. Reading, observation, experiment. [Elective for those students who have taken I; winter term; five times a week.]

III. *Logic.* Jevons-Hill's Elements of Logic as text, with Fowler, Bain, Sidgwick, and others for reference. Treatment of the proposition, immediate and mediate inference, the hypothesis, arguments, and fallacies. Special attention to the principles and methods of induction. [Elective for agricultural seniors.]

IV. *Ethics.* Markenzie's Manual of Ethics, or Muirhead's Elements of Ethics. Lectures and discussions, with readings from Plato, Aristotle, Kant, Mill, Spencer, and others. A critical examination of different ethical theories; chiefly, Hedonism, ancient and modern; Rigorism; and Evolutionary Utilitarianism. [Elective for juniors and seniors; spring term; five times a week.]

BIOLOGY.

The department of biology as at present organized includes botany, zoology and physiology.

Even in the introductory courses laboratory work is made a prominent feature in order that from the first students may become self-reliant.

The equipment of the department has been adequate to the demands made upon it, and as new necessities arise in connection with the several courses, they will be supplied as far as possible from the resources at command.

One of the two rooms of the department is a convenient lecture room having, among its other equipments, a lantern with microscope attachment. This enables the instructor to illustrate on the screen by both lantern and microscope slides the subject under discussion.

Johnson's How Plants Grow, and How Plants Feed. A brief outline of the history of agriculture, followed by a thorough course in the principles of plant culitvation and growth. [Required of agricultural sophomores.]

II. *Soils, Tillage, and Fertilizers.* Taught by lectures and reference books, such as King's The Soil, and Storer's Agriculture. [Required of agricultural sophomores.]

III. *Farm Crops.* Lectures. Planting, irrigating, harvesting, and marketing; laying out and improving farms; farm management and farm accounts. The students' practice will include setting up and running farm machinery, planting and irrigating crops properly. [Required of agricultural sophomores.]

IV, V. *Breeds of Live Stock.* Curtiss's Breeds of Live Stock, Warfield's Cattle Breeding, and Miles' Stock Breeding, supplemented by lectures and practice in judging by scale of points. [Required of agricultural juniors.]

VI. *Stock Feeding and Dairy Management.* Armsby's Cattle Feeding, Henry's Cattle Feeding, and lectures. [Required of agricultural juniors.]

HORTICULTURE.

The instruction in this department aims to give the student a good general foundation in the science of gardening, plant cultivvation, fruit raising, landscape and ornamental gardening. During the spring term of one year, two hours of laboratory work each week in the multiplication of plants, grafting, budding, and making cuttings, are required. The following subjects are offered:

I. *Plant Forcing.* Study of green-houses and hot-beds, and of the cultivation and propagation of vegetables and small fruits. Lectures. [Required of agricultural juniors.]

II. *Pomology.* Pruning, grafting, budding, cuttings, and orcharding. Lectures. [Required of agricultural juniors.]

III. *Landscape and Ornamental Gardening.* Lectures. [Elective for agricultural seniors.]

IV. *Thesis Work.* Pollination, cross fertilization, variation, or other advanced subject. [Elective for agricultural seniors.]

ENTOMOLOGY.

This department aims to give the student an insight into insect life, and to afford some knowledge of economic entomology through the study of injurious insects and the means for their extermination. The following subjects are required:

I. *Elementary.* Packard's Entomology, with Comstock for reference. Lectures. [Required of agricultural juniors.]

II. *Economic Entomology.* Smith's Economic Entomology, supplemented by lectures. [Required of agricultural juniors.]

IRRRIGATION.

The object of this department is to give a general idea of the principles of irrigation practice and water measurement.

I. *Principles.* Effects of water on soil and crops, and measurement of water. Wilson's Irrigation Engineering. Lectures, reference reading, and practical work. [Required of agricultural juniors.]

CHEMISTRY.

The work of all courses in the department of chemistry is experimental and inductive so far as consistent with the acquirement of the necessary amount of general information. Students are from the first encouraged to work independently on lines of investigation in which they are specially interested.

The department of chemistry occupies four rooms in the south end of the Hall of Language. One room contains the analytical balances and the chemical reference library, the second is devoted to the experimental work of the Wyoming Agricultural Experiment Station, the third is a lecture room, and th fourth and largest room is fitted up for the classes in qualitative and quantitative analysis. The department is well equipped for research and analytical work in organic and inorganic chemistry. The following subjects are offered:

I, II. *Elementary.* Storer and Lindsay. The aim of this course is to give students a knowledge of the laws of chemical change, a practical familiarity with the principal elements and compounds, and skill in manipulation of apparatus. [Required of agricultural and mechanical sophomores.]

III. *Qualitative Analysis.* Caldwell's Qualitative Analysis. Students acquire the ability to detect the ordinary acids and bases in any substance. [Required of agricultural and mechanical sophomores.]

IV. *Quantitative Analysis.* Caldwell and Fresenius. Twenty simple gravimetric and volumetric determinations. [Elective for students who have taken III.]

VI. *Inorganic Preparations.* Erdmann's Anleitung zur Darstellung chemischer Präparate. Preparation of a number of difficult compounds and elements. [Open to students who have taken III; spring term; laboratory work ten hours a week.]

VII. *Organic Chemistry.* Remsen's Organic Chemistry. Lectures and recitations on the compounds of carbon. [Required of agricultural juniors; fall term; five times a week.]

VIII. *Organic Preparations.* Gatterman; Practical Methods in Organic Chemistry. [Open to students who have taken VII; winter term; laboratory work ten hours a week.]

XI. *Agricultural Chemistry.* The chemistry of plant growth, and the application of chemical principles to practical agriculture, with special reference to the problems of the arid region. [Required of agricultural juniors; winter term: lectures three hours and laboratory work four hours a week.]

XII. *Applied Chemistry.* Lectures on chemical processes and manufactures not included in metallurgy, and on methods of analysis and control. Most attention is paid to subjects of practical importance in Wyoming; such as petroleum and its products; coal, gas, and coke; building stone and cements; alkalies and acids; beet sugar; glass; air and water supply. [Required of mechanical juniors.]

GEOLOGY.

Most of the instruction in this department is given by lectures, but text-books are used for reference, together with the latest geological reports.

The location of the Agricultural College is exceptionally advantageous for the study of geology. Only a few miles east, the Laramie mountains rise nearly 2,000 feet above the campus, while to the westward the Medicine Bow mountains rise 5,000 feet. Both of these mountain ranges are mineralized, and mining has been carried on for many years. They furnish rich fields for the student of structural and dynamical geology, as well as for those who wish to study almost new Archæan exposures. Flanking these ranges are Paleozoic, Mesozoic, and Cenozoic rocks that have been exposed by the mountain making and subsequent erosion, so that a student may easily make himself familiar with the entire series of Rocky Mountain sedimentary rocks. The working collections of rocks and fossils in the department are not large, but are well selected and are increasing in size very rapidly. The collection of Mesozoic invertebrates is very complete and the collection of Jurassic vertebrates is the second in size in the United States. To those who wish to study economic geology special inducements can be offered, since ores of economic value are numerous, and are only a short distance away from the university. The plains are also well supplied with mines of coal and deposits of clay, gypsum and building stones.

The following list of books is used for reference and text work in this department: Le Conte, Dana, Geikie, Kayser-Lake, Lapparent, Tarr, Zittel, and Nicholson and Lydekker. The following subjects are offered:

I. *Dynamical and Structural.* Geological forces, conditions in which stratified rocks are found, and general topography. Lectures; Le Conte and Dana as texts. [Required of agricultural juniors.]

II. *Mineralogical.* Elementary study of mineralogy, in which a student is required to determine fifty species of common minerals with the blow-pipe. Lectures; Crosby and Brush as texts. [Required of agricultural juniors.]

III. *Historical.* Study of fossilized life associated with stratified rocks, and methods of determining formations from associated fossil life. Lectures; Le Conte and Dana as texts. [Required of agricultural juniors.]

IV. *Economic.* Study of the minerals of economic importance and methods of preparing them for the market. Lectures; Kemp and Tarr as texts. [Elective for agricultural seniors.]

V. *Paleontological.* Elementary course in paleontology. Lectures; Nicholson and Lydekker as text. [Elective for agricultural seniors.]

VI. *Advanced.* Course arranged to suit the needs of students. One week in the field. [Elective for agricultural seniors.]

HISTORY.

The purpose of the department of history is to create a taste for historical reading and give the ability to comprehend rightly the events of the times by applying the experience of the past to the conditions and problems of today. The aim is not the accumulation of a mass of facts and dates, but the acquisition of a right comprehension of great historical events.

Text-books are used, especially in the preparatory classes; but the study of the assigned lessons is supplemented by reading different authorities on the same subject and by lectures. The historical library has been greatly enlarged during the past year and is at the disposal of the students in this department: The following courses are offered:

I. *England.* Montgomery's English History. [Required of preparatory students.]

II, III. *Mediaeval and Modern.* Myer's Mediaeval and Modern History. [Required of preparatory students.]

IV. *Greece.* Myers' History of Greece; Guerber's Mythology. [Elective for agricultural seniors.]

V, VI, VII. *Middle Ages.* Thatcher and Schwill. Lectures and supplementary reading. [Elective for agricultural seniors.]

ENGLISH.

The aim of the preparatory work in this department is to teach the students to understand and use the English language correctly and to cultivate in them a taste for the best literature. A thorough mastery of English grammar is required before entrance to the Preparatory Year.

The student's work in literature is made to furnish the occasion as well as the material for the preparation of essays. These essays are subject to criticism both in the class and with the individual writers.

The formal study of rhetoric is designed to ground the student in the principles of English composition and to cultivate his literary sense by analytical study.

The work in oratory is of a practical character. An effort is made to secure reading that shall be intelligent, natural and forcible, and to develop spontaneous expression from the mental side. The student meets the instructor personally for rehearsal and criticism.

IX. *Trigonometry.* Wells' New Trigonometry. The development of the general formulae and their application to the solution of triangles, polygons, and original field problems. [Required of agricultural juniors and mechanical sophomores.]

X. *Analytical Geometry.* Wentworth's Analytical Geometry. The analytical geometry of the straight line, circle, and conic sections; including a general discussion of the general equation of the second degree, and an introduction to the geometry of three dimensions. [Required of mechanical juniors, elective for agricultural seniors.]

XI, XII. *Calculus.* Osborne's Calculus. Differentiation of functions, successive differentiation, indeterminate forms, development of functions in series, maxima and minima, functions of two or more variables, tangents, normals, asymptotes, direction of curvature, singular points, curve tracing, evolutes, envelopes, and order of contact. Integration, application to geometry and mechanics, successive integration, integration of rational fractions, integration by rationalization, by parts and by series, lengths and areas of plane curves, areas of surfaces of revolution, and volumes of solids. [Required of mechanical juniors; elective for agricultural seniors.]

PHYSICS.

The aims of this department are to cultivate in the student habits of thoughtful observation, intelligent and rapid manipulation, and to give him a general knowledge of natural phenomena. In all courses the subjects are studied from the experimental side, the student spending at least one-half of the time allotted to the work in the laboratory under the direct supervision of the professor in charge.

The following subjects are offered:

I, II, III. *Elementary.* Carhart and Chute's Elements of Physics; Allen's Laboratory Physics. The properties of matter; mechanics of solids and liquids. Heat, sound, and light. Magnetism and electricity. [Required of freshmen.]

IV, V, VI. *General.* Barker's Physics. Outlined experiments with reference to laboratory manuals. Physical quantities, kinematics, dynamics, work and energy, attraction and potential, and properties of matter. Energy of mass vibration, molecular kinetic energy, radiant energy. Energy of aether-stress, energy of aether-vortices, energy of aether-flow, and the electromagnetic character of radiation. [Required of mechanical juniors and elective for agricultural seniors.]

VII. *Electric Measurements.* Measurements of resistances, calibration of amperemeters and voltmeters, calculation of the electromotive force of batteries and dynamos, magnetic determinations, heating effect of currents, etc. [Elective for agricultural seniors.]

MECHANICS.

The aim of the instruction in this department is to give the student a thorough insight into the general principles governing prime movers and mechanical movements, and acquaintance with the methods in which these principles may be applied and combined in order to produce the desired effect in all branches of engineering. Instruction is also given in subjects which are rather more technical than theoretical, and the application of theory to practice is never lost sight of. The work is fully illustrated by frequent reference to the engineering and mechanical equipment of the university and other available sources.

The following subjects are required of mechanical students:

I, II. *Founding.* Lectures on core making, loam, dry and green sand molding; cast iron; flasks, facing, finishing, etc.; also on preparing, charging, tapping out, and stopping up the cupola. [Required of mechanical freshmen.]

X. *Parts of Machines.* Designing gears, cams, and parts of machines which apply to the study of Mechanics II. [Required of mechanical juniors.]

XI. *Blue Prints.* Tracing and making drawings to be used in the shops. [Required of mechanical juniors.]

XII. *Machine Designing.* Designing a boiler or some simple machines; the design to be as original as possible. [Required of mechanical seniors.]

XIII. *Steam Engine Drawing.* This subject is to accompany the work in Mechanics V and VI. [Required of mechanical seniors.]

INDUSTRIALS.

This department is intended to simplify mechanical engineering by teaching practical work in connection with the theory. It aims also to present the practical side of production by running the machine shops as nearly as possible on the principle of actual manufacturing establishments.

I, II. *Wood Working.* Lectures on the care and management of carpenters' tools; exercises in lining, planing, sawing, notching, splicing mortising, and tenoning. Bench work in wood; exercises in dovetailing, framing, paneling, and special work for the department. [Required of agricultural and mechanical preparatory students.]

III. *Wood Turning.* Exercises in straight and curved turning, compound curves, etc. [Required of agricultural and mechanical preparatory students.]

IV. *Pattern Making.* A large variety of patterns, including parts of machines, are made for use in the foundry. [Required of mechanical freshmen.]

V, VI. *Foundry Practice.* Exercises in moulding, pouring, charging, and managing the cupola. The castings obtained are used by the students in the machine room. [Required of mechanical freshmen.]

VII. *Iron Work.* Exercises in filing and chipping, and the use of the drill press. [Required of mechanical sophomores.]

VIII. *Iron Planing.* Exercises and special work. [Required of mechanical sophomores.]

IX. *The Engine Lathe.* An elementary course; tapering, screw cuting, etc. [Required of mechanical sophomores.]

X. *The Engine Lathe, Advanced.* Special work: turning up parts of machines, and work for the department. [Required of mechanical juniors.]

XI. *Milling.* Exercises in milling, sawing, gear cutting, spiral cutting, and work on parts of machines. [Required of mechanical juniors.]

XII. *Engineering Laboratory.* Testing the efficiency of boilers, and inspection visits. [Required of mechanical juniors.]

XIII. *Engineering Laboratory.* Testing steam engines, learning the principles and operation of the steam engine indicator and rigging; inspection visits. [Required of mechanical seniors.]

XIV. *Shop Engineering.* General work in shop management, lining shaftings, and setting machines; inspection visits [Required of mechanical seniors.]

XV. *Experimental Laboratory.* A thesis is produced in connection with experimental work. [Required of mechanical seniors.]

Special subjects of experiment are arranged for those who have taken the baccalaureate of science in mechanics and wish to take graduate work.

MILITARY SCIENCE AND TACTICS.

The department of Military Science and Tactics is established in accordance with the requirements of an Act of Congress donating public lands to colleges, one of the conditions being that military tactics shall be taught. It is under the control of the officer of the regular army, detailed by the War Department for its duty, without any expense to the State, under the provisions of Section 1225, Revised Statutes of the United States. One hundred and fifty Springfield rifles (cadet pattern; similar to those used at West Point) and equipments, and cannon and sabres for artillery and cavalry practice, are loaned to the college by the U. S. Ordnance Department. An allowance of ammunition is annually supplied by the general government for purposes of target practice. All students are required to drill throughout the year. The cadet officers are appointed by the commandant of cadets, subject to the approval of the president. The commissioned officers are usually selected from the senior class, the sergeants from the junior class and the corporals from the sophomore class, general merit and military efficiency being the qualifications considered.

Besides obtaining the excellent physical results which follow systematic and regular military training, the *morale* of the students will be thus improved. The virtues of patriotism, honor, and truthfulness are cultivated, and habits of neatness promptness and obedience are insisted upon.

The rules prescribed by the President of the United States for the government of officers of the army detailed as Professors of Military Science and Tactics require the following course of instruction:

1. The course of instruction shall be both practical and theoretical, and shall be so arranged as to occupy at least one hour per week for theoretical instruction, and at least two hours per week for practical instruction.

2. The practical course in infantry shall embrace small-arm target practice, and, as far as possible, all the movements prescribed by the drill regulations of the United States army applicable to a battalion. Instruction in artillery shall embrace, as far as practicable, such portions of the United States drill regulations as pertain to the formation of detachments, manual

of the piece, mechanical maneuvers, aiming drill, saber exercise, and target practice. Instruction should also include the duty of sentinels, and where practicable, castrametation. Such instruction shall be given by the Professor of Military Science and Tactics personally, or under his immediate supervision.

3. Theoretical instruction shall be by recitations and lectures personally conducted and given by the Professor of Military Science and Tactics, and shall include, as far as practicable, a systematic and progressive course in the following subjects: The drill regulations of the United States army, the preparation of the usual reports and returns pertaining to a company, the organization and administration of the United States army, and the elementary principles governing in the art of war.

The military department shall be subject to inspection under the authority of the President of the United States; such inspection shall be made, when practicable, near the close of the college year. The inspecting officer shall, upon his arrival at the institution, report to the President or other administrative officer in order to obtain from him the necessary facilities for the performance of his duty. A copy of the report of inspection will be furnished the President of the institution by the War Department.

Military drill has become a feature of all the courses in the University, and it is required that all students appear at the drill in uniform. Students are advised to come to the college without specially providing themselves with new clothes and to arrange to wear the cadet uniform habitually while at college.

The cost of the uniform is about $14.50. The grade of suiting, including the cap, wears well and proves to be economical.

All male students are expected to provide themselves witl uniforms. It consists of a blouse, trousers, and cap, modeled after the West Point uniform, with raised gilt buttons.

COURSE IN MILITARY SCIENCE.

Practical.—Cadets are divided into two classes, First Year and Subsequent Year Cadets.

For all cadets: Practical instruction comprises the schools of the soldier, squad, and company in normal and extended order (Infantry Drill Regulations), guard mounting and guard duty, gallery and range target practice.

For Subsequent Year Cadets: In addition to the above comprises artillery drill, saber exercise, and military signaling with flag and heliograph.

Theoretical.—Cadets are divided into four classes. The winter term is especially devoted to this instruction, which includes the following:

First Year Cadets: Infantry Drill Regulations, including the schools of the soldier, squad, and company, in normal and extended order.

Second Year Cadets: School of the battalion and ceremonies (Infantry Drill Regulations), and U. S. Manual of Guard Duty.

Freshman Class: "Elements of Military Science," Pettit.

Sophomore Class: U. S. Army Regulations, muster roll and returns, etc., Military Law, and State Laws Relating to the National Guard.

The corps of cadets has this year been divided into two companies, with the commandant acting as major. The number of young men in the drill has been seventy-seven.

THE LIBRARY.

The library, which is also the general reading room of the University, is situated on the second floor, in the north wing of the main building. This is a large well-lighted and ventilated apartment. The college students use this room during vacant hours from 8:30 a. m. to 12 m., and from 1 to 3:15 p. m.

The students at stated hours during six days of the week, have access to the books and periodicals. Three volumes may be taken by any one individual and kept from the shelves for a period of two weeks. Books reserved at the instance of professors as collateral reading for their courses are shelved in their respective rooms, and can be taken out only on application to such professors, who are responsible for them during the period of their reservation.

The library contains 9,302 bound volumes, and in addition several thousand unbound bulletins and reports on agricultural and scientific subjects.

There have been added to the University library during the year 1899-1900, 2,400 bound volumes and 1,000 pamphlets, including Experiment Station bulletins and publications from the Department of Agriculture at Washington, D. C.

The Board of Trustees of the University, at its annual meeting in May, 1900, made an appropriation of $5,000 for reference books for the library. The scientific books as purchased, after being catalogued, are placed in the reference libraries in the respective laboratories in the University, the books for more general use being placed in the library proper. A pleasing increase of interest in the library is being shown by the students continually; the books are being consulted with greater care, and with results noticeable in the class-room.

The following agricultural papers and Wyoming newspapers are sent to the University:

Arkansas—
  Farmer.

California—
  Press and Horticulturist.
  The Call.
  West American Science.

Colorado—
  Farmer.
  The Field and Farm.

Georgia—
  The Southern Cultivator.

Illinois—
  Prairie Farmer.
  Orange Judd Farmer.
  Farmer's Review.
  The Farmer's Magazine.
  The Elgin Dairy Report.
  Irrigation Age.

Indiana—
  Clover Leaf.

Iowa—
  Iowa Homestead.

Kansas—
  Farmer.

Kentucky—
  The Industrial American.

Louisiana—
  Planter.

Maryland—
  Farmer.
  Southern State.
  Baltimore Weekly Sun.

Massachusetts—
  Farm and Home.
  Ploughman.
  Our Grange Home.
  American Cultivator.
  New England Farmer.

Michigan—
  Grange Visitor.

Missouri—
  National Dairyman.

Nebraska—
  Western Resources.

New Hampshire—
  Mirror and Farmer.

New Mexico—
  Southwestern Farm and Orchard.

New York—
  American Agriculturist.
  Rural New Yorker.
  Sugar Trade Journal.

Ohio—
  American Grange Bulletin.

Ontario—
  Farmers' Advocate.

Pennsylvania—
  Germantown Telegraph.
  Public Ledger, daily.

Virginia—
  Southern Planter.
  The Progressive South.

Washington—
  Northwest Mining Review.

- Wisconsin—
  - Hoard's Dairyman.
- State Papers—
  - Bill Barlow's Budget.
  - Boomerang.
  - Carbon County Journal.
  - Central Wyoming News.
  - Cheyenne Tribune.
  - Fremont County Gazette.
  - Laramie Times.
  - Newcastle News-Journal.
  - News-Register.
  - Otto Courier.
  - Rock Springs Independent.
  - Rock Springs Miner.
  - Saratoga Lyre.
  - Saratoga Sun.
  - Sheridan Journal.
  - Sheridan Post.
  - Sun-Leader.
  - Wheatland World.
  - Wyoming Press.

The scientific and general periodicals taken by the library and kept on the tables of the reading room are:

Agricultural Science.
American Gardening.
American Geologist.
American Historical Review.
American Journal of Mathematics.
American Journal of Science.
American Machinist.
American Naturalist.
Arena.
Art Interchange.
Asa Gray.
Atlantic Monthly.
Auk.
Berichte der Deutschen Chemischen Gesellschaft.
Biologisches Central-Blatt.
Book News.
Botanical Gazette.
Bulletin of the Torrey Botanical Club.
Carpenter and Builder.
Cassier's Magazine.
Century.
Cosmopolitan.
Cumulative Index.
Die Garten-laube.
Education.
Educational Review.
Electrical World.
Engineering Magazine.
Engineering Record.
Erythea.
Etude.
Fern Bulletin.
Fliegende Blaetter.
Forum.
Garden and Forest.

Germania.
Great Round World.
Harper's Monthly.
Harper's Weekly.
Home Study.
Journal of the Society of Chemical Industry.
Journal of the American Chemical Society.
Journal of the British Chemical Society.
Kunkel's Musical Review.
Literary Digest.
Meehan's Magazine.
Metal Worker.
Microscope.
Microscopical Journal.
Mining and Scientific News.
Monist.
Nation.
Nature.
North American Review.
Outlook.
Philosophical Review.
Photographic Times.
Physical Review.
Plant World.
Political Science Monthly.
Popular Science Monthly.
Power.
Psychological Review.
Public Libraries.
Quarterly Journal of Pure and Applied Mathematics.
Review of Reviews.
Science.
Scientific American and Supplement.
Scribner.
Sociology.
Studio.
St. Louis and Canadian Photographer.
Terrestrial Magnetism.
Young Men's Era.
Western Electrician.

The University now uses the Dewey Decimal Card Catalogue system, and in addition to the regular cards has those coming from the Department of Agriculture at Washington, containing a complete list of publications sent from that department and its several branches in connection with the Experiment Station work.

TREASURER'S REPORT.

THE UNIVERSITY OF WYOMING,
AGRICULTURAL COLLEGE.

Report of the Treasurer of said institution to the governor of the state of Wyoming of amount received under act of Congress of August 30, 1890, in aid of Colleges of Agriculture and the Mechanic Arts, and of the disbursements thereof, to and including June 30, 1900.

Balance on hand July 1, 1899	$12,489.33
Date of receipt of installment for 1899-1900, Nov. 16, 1899	25,000.00
Total available for year ending June 30, 1900	$37,489.33

Disbursements thereof for and during the year ending June 30, 1900.

Agriculture	$1,729.43	
Mechanic Arts	3,873.42	
English Language	3,397.88	
Mathematical Science	2,897.95	
Natural or Physical Sciences	9,739.44	
Economic Sciences	4,472.73	
Total expended during the year		$26,110.85
Balance remaining unexpended July 1, 1900		$11,378.48

Outstanding contracts for facilities not yet delivered, chargeable to this unexpended balance, amount to $9,503. Commissioner of Education. Letter July 12, 1900.

We hereby certify that the above account is correct and true, and, together with the itemized account attached, truly represents the details of expenditures for the period and by the institution named, and that said expenditures were applied only to instruction in agriculture, the mechanic arts, the English language, and the various branches of mathematical, physical, natural, and economic science, with special reference to their application in the industries of life and to the facilities for such instruction.

JOHN C. DAVIS, Treasurer.
GRACE RAYMOND HEBARD, Secretary.

Courses of Study.

For explanation of the Roman numerals, see departmental statements on preceding pages. The Arabic numerals indicate the number of hours a week. Where no numeral appears, 5 is understood. Two hours of laboratory, shop or field work are counted as equivalent to one hour of recitation or lecture.

AGRICULTURAL COURSE.

PREPARATORY YEAR.

FALL TERM.	WINTER TERM.	SPRING TERM.
History, I. English, I. German, I. Mathematics, I. Industrials, I.	History, II. English, II. Mathematics, II. German, II. Industrials, II.	History, III. English, III. Mathematics, III. German, III. Industrials, III.

FRESHMAN YEAR.

Physics, I. Mathematics, IV. Drawing, I German, IV. Botany, I English, VII.	Physics, II. Mathematics, V. Drawing, II. German, VI. Botany, II. English, VIII.	Physics, III. Mathematics, VI. Drawing, III German, VII. Botany, III. English, IX.

SOPHOMORE YEAR.

Zoölogy, I. Entomology, I. Chemistry, I. English, X, 1. Agriculture, I, 4.	Zoology, II. Entomology, II. Chemistry, II. English, XI, 1. Agriculture, II, 4.	Zoology, III. Mathematics. IX. Chemistry, III. English, XII. 1. Agriculture, III, 4.

JUNIOR YEAR.

Geology, I. Philosophy, I. Agriculture, IV. Chemistry, VII. Elective, 5 hours.	Geology, II. Horticulture, I. Agriculture, V. Chemistry, XI. Elective, 5 hours.	Geology, III. Horticulture, II. Agriculture. VI Meteorology, I, 2. Irrigation, I, 3. Elective, 5 hours.

SENIOR YEAR.

Political Science, IV. English, XIX, 1. Elective, 10 hours.	English, XX, 1. Physiology. Elective, 10 hours.	English, XXI, 1. Elective, 15 hours.

MECHANICAL COURSE.

For explanation of the Roman numerals, see departmental statements on preceding pages. The Arabic numerals indicate the number of hours a week. Where no numeral appears, 5 is understood. Two hours of laboratory, shop or field work are counted as equivalent to one hour of recitation or lecture.

PREPARATORY YEAR.

FALL TERM.	WINTER TERM.	SPRING TERM.
Mathematics, I.	Mathematics, II.	Mathematics, III.
History, I.	History, II.	History, III.
English, I.	English, II.	English, III.
Drawing, I.	Drawing, II.	Drawing, III.
Industrials, I.	Industrials, II.	Industrials, III.

FRESHMAN YEAR.

Mathematics, IV.	Mathematics, V.	Mathematics, VI.
German, I.	German, II.	German, III.
Physics, I.	Physics, II.	Physics, III.
Drawing, IV.	Drawing, V.	Drawing, VI.
Industrials, IV.	Industrials, V, 8.	Industrials, VI, 8.
	Mechanics, I, 2.	Mechanics, II, 2.

SOPHOMORE YEAR.

Mathematics, VII.	Mathematics, VIII.	Mathematics, IX.
German, IV.	German, V.	German, VI.
Chemistry, I.	Chemistry, II.	Chemistry, III.
Drawing, VII, 4.	Drawing, VIII, 4.	Drawing, IX, 4.
English, VII, 1.	English, VIII, 1.	English, IX, 1.
Elective, 5.	Elective, 5.	Elective, 5.

JUNIOR YEAR.

Mathematics, X.	Mathematics, XI.	Mathematics. XII.
Mechanics, III.	Mechanics, IV.	Mechanics, V.
Elective, 5.	Elective, 5.	Elective, 5.
Drawing, 10, 4.	Drawing, XI, 4.	Drawing, XII, 4.
English, X, 1.	English, XI, 1.	English, XII, 1.
Industrials, VII.	Industrials, VIII.	Industrials, IX.

SENIOR YEAR.

Mechanics, VI.	Mechanics, VII.	Mechanics, VIII.
Elective, 5.	Elective, 5.	Elective, 5.
Political Science. IV.	Thesis.	Thesis.
English, XIX, 1.	English, XX, 1.	English, XXI, 1.
Industrials, X.	Industrials, XI.	Industrials, XII.
Drawing, XIII.		

UNIVERSITY OF WYOMING.

LARAMIE, WYOMING.

Report of the President of Said Institution to the Secretary of the Interior and the Secretary of Agriculture, as Required by Act of Congress of August 30, 1890, in Aid of Colleges of Agriculture and the Mechanic Arts.

RECEIPTS FOR AND DURING THE YEAR ENDING JUNE 30, 1900.

1.	Balance on hand July 1, 1899, over and above all indebtedness (excluding funded debt, if any)	$15,481.87
2.	State aid: (a) Income from endowment granted by state	
	(b) Appropriation for current expenses	8,726.51
	(c) Appropriations for building or for other special purposes	6,118.26
3.	Federal aid: (a) Income from land grant, act of July 2, 1862	
	(b) Additional endowment, act of August 30, 1890	25,000.00
	(c) For experiment stations, act of March 2, 1887	15,000.00
4.	Fees and all other sources	928.70
	Total	$71,255.34

EXPENDITURES FOR AND DURING THE YEAR ENDED JUNE 30, 1900.

(Not necessarily a balance sheet as compared with Division II above.)

1. Instruction in the subjects specified in Sec. 1, act of August 30, 1890[*]	$18,445.00
2. Instruction in all other subjects, if any, not mentioned in Question 1 of this series	3,700.00
3. Administrative expenses (President's, Secretary's, Treasurer's, Librarian's salary, clerical service, fuel light, etc.)[**]	3,300.00
4. Experiment Station	15,340.35
Total	$40,785.35

PROPERTY, YEAR ENDED JUNE 30, 1900.

Value of all buildings, $111,540; of other equipment, $61,500.

Value of above property (an estimate only is expected) not used for instruction in the subjects specified in section 1 of act of August 30, 1890, Buildings (all used); of other equipment, $17,000.

Total number of acres, 416; acres under cultivation, 180; acres used for experiments, 180; value of farm lands, $10,600; amount of all endowment funds, $7,000. (Act July 2, 1862.)

Number of bound volumes June 30, 1900, 9,300; pamphlets, 5,500.

FACULTY DURING THE YEAR ENDED JUNE 30, 1900.

	Male.	Female.
1. College of Agriculture and Mechanic Arts:		
(a) Preparatory classes	10	3
(b) Collegiate and special classes	10	3
(c) Total, counting none twice	10	3
2. Number in all other departments (excepting duplicates	3	1
3. Number of staff of Experiment Station	6	1

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[*] The answer to this question will include not only the amount received under the act of August 30, 1890 ("Morrill Act"), but also all amounts that are expended for the subjects specified in that act, irrespective of the character of the funds the amounts may be drawn from (State, tuition fees, or endowment, etc.)

[**] It may be convenient for many institutions to answer 2 and 3 as one question. Cost of new buildings is given under Division I.

STUDENTS DURING THE YEAR ENDED JUNE 30, 1900.

	Male.	Female.
(a) Preparatory classes	0	0
(b) Collegiate and special classes	15	0
(c) Post graduate courses	0	0
Total, counting none twice	15	0
2. Number in all other departments	90	83

3. Number of students that pursued courses in agriculture, 2; mechanical engineering, 13; electrical engineering, 0; mining engineering, 11; architecture, 0; household economy, 0; veterinary science, 0; military tactics, 66. It is not expected that the sum of these figures will equal the number of students given above.)

4. What degrees and how many of each kind were conferred in 1899-1900?

On men, 8 (B. A., 3; B. S., 3; M. A., 1; M. Ped., 1).
On women, 9 (B. A., 2; B. Ped., 7).

5. What and how many honorary degrees were conferred in 1899-1900? None.

[Signed] ELMER E. SMILEY,
President.

..THE..

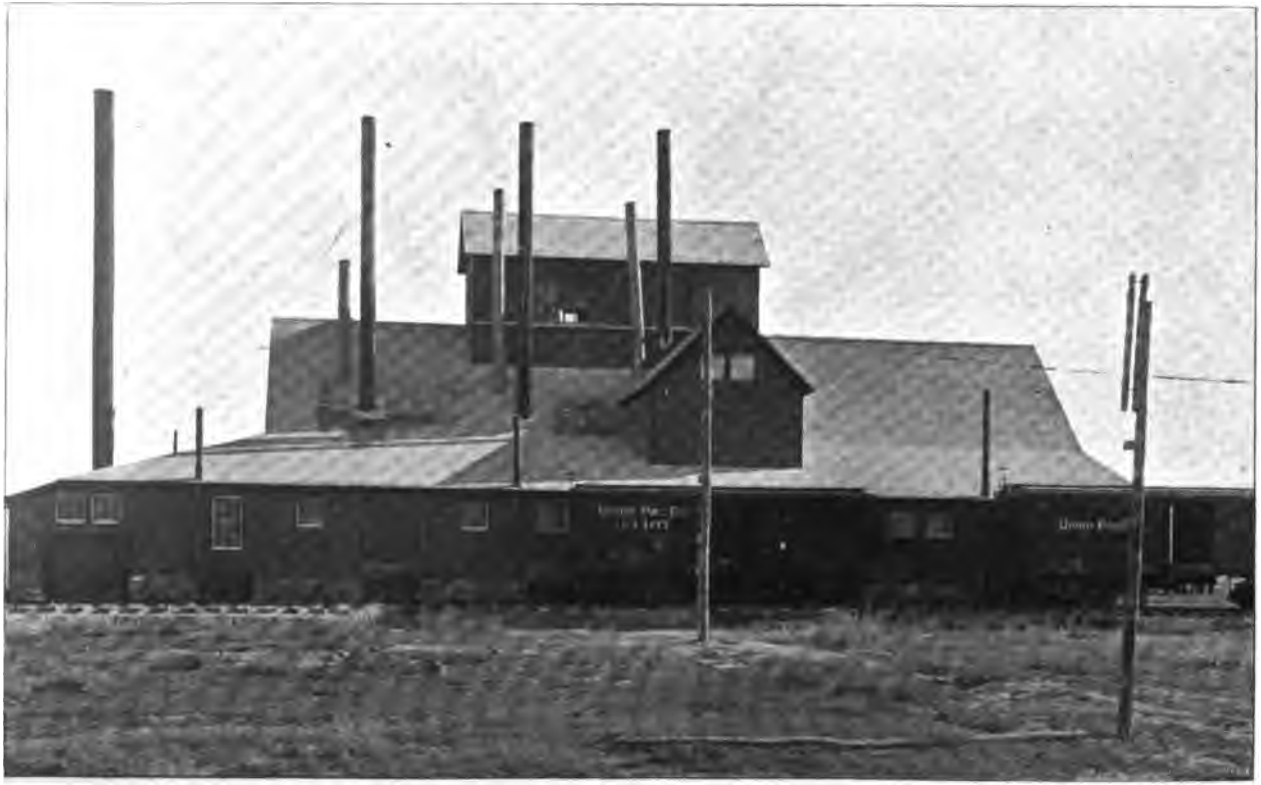
Laramie Cement Plaster.

BY

E. E. SLOSSON AND R. B. MOUDY.

(PUBLISHED AS PART OF THE TENTH ANNUAL REPORT OF
THE WYOMING COLLEGE OF AGRICULTURE
AND MECHANICS.)

LARAMIE, 1900.



LARAMIE CEMENT PLASTER WORKS.

The Laramie Cement Plaster Industry*

E. E. SLOSSON AND R. B. MOUDY.

There are a large number of gypsum deposits in Wyoming varying in composition from pure crystal to gypsite powder. At Red Buttes, since 1889, plaster of Paris and stucco of fine quality have been manufactured, and since 1897 the Consolidated Company has been putting on the market plaster made from the ground gypsum rock. Some tests made on the product of this plant are included in this bulletin and further attention will be paid to it when the gypsum deposits of the state are studied.

The Laramie cement plaster, which is the subject of the investigations here reported, is made from a deposit of gypsite just south of Laramie. This bed covers about 180 acres and has been worked by the Standard Cement Plaster Company since 1896. Their annual output is now about 2500 tons.

THE GEOLOGY OF THE LARAMIE GYPSITE DEPOSIT.†

The Triassic formation, or "red beds" as it is commonly called, which is exposed all along the eastern side of the Laramie Plains, contains a great deal of gypsum and one stratum of considerable thickness near the bottom of the formation and only a little above the sandstone and limestone of the Permian and Carboniferous. This bed was struck in the University artesian well at a depth of

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*This is one of a series of reports issued by various departments of the University on the natural resources of the State and the industries founded upon them. Three bulletins have been published on petroleum, one on coal, one on mineral in general, one on soda deposit and a large number on botany and agriculture.

†From information by Professor W. C. Knight.

595 feet and the Permian sandstone at about 800 feet. The Red Buttes gypsum rock is found in this formation and doubtless the gypsum outcrop could be found at almost any point along the eastern side of the Laramie Plains within a half mile of the limestone and sandstone exposures which form the western slope of the Laramie mountains. The silica and limestone washed down from these exposures have mixed with the disintegrated gypsum of the Triassic beds and have been deposited in depressions of the plains, forming numerous beds of gypsite or gypsum earth. These deposits can often be detected by the whiteness of the soil and the peculiar vegetation, which consists of clumps of grease-wood (*Sarcobatus vermiculatus*), such as grows on the alkali flats.[*]

The Laramie gypsite bed has an average depth of about nine feet. From a few inches below the surface to about seven feet it is pure gypsite powder, then comes a red layer of five inches, and below this a foot or more of the white gypsite powder resting on gravel and red clay. The plaster material is as fine as flour, requiring no grinding or even sifting. It is plowed, harrowed and scraped up, calcined and loaded on the cars.

THE CHEMISTRY OF CEMENT PLASTER.

In gypsum four molecules of water of crystallization are combined with two molecules of calcium sulphate $2CaSO_4.4H_2O$. This may be regarded as the di-calcium salt of two molecules of ortho-sulphuric acid, H_6O_6S. On heating this up to 262°F., according to Le Chatelier[†], three of the four molecules of water are driven off, leaving $2CaSO_4.H_2O$. This is the ordinary plaster of Paris and the principal ingredient in cement plaster. It may be regarded as the di-calcium salt of the acid $H_6S_2O_9$ and as such would be represented by the symbol $H_2Ca_2S_2O_9$. The fourth and last molecule of water is driven off between 340° and 381°F., leaving calcium sulphate completely dehydrated. Calcium sulphate prepared in this way and not heated higher than is necessary to completely dehydrate it takes up one molecule of water very readily, even absorbing it from ordinary air,* to form $2CaSO_4.H_2O$, plaster of Paris. If heated still higher to 430°-650°F., or to a red heat, another change takes place and the calcium sulphate, although it has the same composition as that prepared at 340°, yet differs from it very decidedly in its properties. It takes up water very slowly, and according to Zulkowski† only enough to form $2CaSO_4.2H_2O$. Plaster in this condition is known as "over-burnt" or "dead-burnt," and is useless for practical purposes.

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[*] According to the California Experiment Station the presence of greasewood indicates black alkali (sodium carbonate) in the soil. In Wyoming it is characteristic of the white alkali (sodium sulphate), and gypsum where there is no trace of sodium carbonate.

[†] Thorpe: Dictionary of Applied Chemistry, I. 471.

The object of the plaster-maker is then to drive off three-fourths of the combined water of the gypsum. This can be done by heating to 340°F., but in practice a temperature of 380-390°F. is used, which doubtless drives off part of the last quarter of the water, but this does not matter, because, as already said, it is restored by the moisture of the air. The composition of pure gypsum is, then:

Calcium sulphate	79.1%	100.0	parts
Water	20.9	26.4	
	100.0	126.4	

And of pure plaster of Paris is:

Calcium sulphate	93.8%	100.0	parts
Water	6.2	6.6	
	100.0	106.6	

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*Potilitzin: Watts' Dictionary of Chemistry, IV. 569.

†Jour. of Soc. of Chem. Ind. XVIII. 918.

Gypsite, or the material from which cement plaster is made, contains beside the gypsum some twenty percent of other material, such as clay, sand and limestone. The composition of the different products on the market is very variable and cannot be supposed to be alike in their value and use, but what difference a greater or less amount of lime or silica or magnesia has on the working of the plaster has not been determined. The action of these substances as a whole is to retard the time of setting and reduce the strength as compared with pure plaster of Paris.

THE MANUFACTURE OF CEMENT PLASTER AT LARAMIE

The kettles used in the manufacture of cement plaster at Laramie hold a charge of about five tons without boiling over, and the run is made in about three hours.

One run was watched from beginning to end and samples taken at intervals for analyses. The results were as follows:

Time from beginning		Temperature °F	Per Cent Water in Cement	Pounds Water per 100 Pounds Calcium Sulphate	Remarks
hrs.	*min.*				
0	0	65°	32.02	59.93	Charge put in.
2	0	310°	11.69	16 85	Kettle filled.
2	20	328°	9.69	13.66	Boiling
2	30	340°	8.34	12.41	End of first boil.
2	50	390°	6 75	9.17	Dumped.

The gypsite used in this run was quite damp and stuck together when squeezed in the hand. To determine the amount of moisture, a sample was kept in a desiccator over concentrated sulphuric acid for four months, and two other samples were heated in test-tubes in a paraffin bath at 65°C. to constant weight.

WATER IN THE GYPSUM EARTH.

1.	Moisture from desiccator sample	15.61%
2.	Moisture from test tube sample	15.89
3.	Moisture from test tube sample	15.65
4.	Water of crystallization in No. 1	19.50
5.	Total water (calculated from Nos. 1 and 4)	32.02
6.	Total water by direct determination	29.95

As the charge of five tons is put in, an operation which lasts about two hours when the material is wet, it sinks to the bottom, but as the temperature increases the powder rises and flows in waves around the kettle as it is stirred by the agitator. The kettle at this stage looks as though filled with a liquid boiling violently. This is due to the expulsion of the water of crystallization. When the first part of the water is driven off the mass sinks down and presents a perfectly smooth and level surface, unbroken by bubbles. As the heat is continued, a second boil begins similar to the first, but shorter, and the thermometer shows a rapid rise of temperature. As the boiling subsides and the temperature is 380-390°F., the operation is complete and the plaster is finished.

By calculating the amount of water present on the constant basis of 100 parts of the calcium sulphate, as is done in the fourth column of the table, we can follow the chemical changes at each stage. We have at the beginning nearly 60 parts water, of which 26.4 is water of crystallization. The first boil consists in driving off the hygroscopic or accidental moisture and part of the water of crystallization. At the end of the first boil the material contains about 13 parts of water per hundred of calcium sulphate, that is, half the original amount of water of crystallization (26.4), has been driven off. If we take the water content as it is falling after the first boil we have 13.04, which corresponds closely to the theoretical 13.2, or half the water of crystallization. From the analysis and from the behavior of the gypsite at this point it is very probable we have formed at the end of the first stage of the process the monohydrate $CaSO_4.H_2O$, which, however, has not been isolated.

At the end of the process we have 9.17 parts water per hundred of sulphate, while theory requires for plaster of Paris, $2CaSO_4.H_2O$, 6.6, showing that the dehydration is not carried quite far enough, and it is probably impossible to complete the operation without danger of overheating some parts.

The cement plaster made in the run just described had the following composition:*

Water	6.93%
Insoluble residue (silica)	5.50
Alumina, Al_2O_3	.59
Lime, CaO	37.11
Magnesia, MgO	1.45
Sulphuric acid, SO_3	43.37
Carbonic acid (by diff.)	5.05
	100.00

These may be combined as follows:

Water	6.93%
Insoluble residue (silica)	5.50
Alumina, Al_2O_3	.59
Magnesium carbonate	3.04
Calcium carbonate	7.86
Calcium sulphate	73.73
Calcium oxide	2.35
	100.00

There was a trace of iron but too small to determine. It will be seen that there are not enough acids to combine with the bases. This fact has also been noticed by Bailey*, who attributes it to the presence of calcium silicate. This is very probable, but this sample gave an alkaline reaction with litmus and turmeric paper, showing the presence of a small amount of free lime, perhaps due to local overheating.

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*Analysis by R. B. Moudy.

THE EFFECT OF SAND ON THE CRUSHING STRENGTH.

To determine whether the addition of sand weakens or strengthens the cement plaster, a series of tests was made on two-inch cubes made from the neat cement and cement mixed with amounts of sand running from one-eighth to one and three-quarters the weight of the cement. From six to ten blocks were made of each mixture, as in spite of all efforts to secure uniformity there was a wide variation, as is shown in the table. . This is due apparently to the unequal distribution of minute air bubbles, the presence of which could not be avoided without using too much water or otherwise making the conditions very different from those of practical work.

The sand used was obtained from the Laramie river and was composed of sharp angled granitic fragments. It was sifted through a millimeter sieve. In making the blocks for testing, 400 grams of the cement was weighed out, mixed dry with the weighed amount of sand, then a measured quantity of distilled water was added to make the mixture of the proper consistency. More water is used for the same amount of cement as the amount of sand is increased, but less water in proportion to the total weight of the mixture. After stirring carefully a minute it was poured into the gang moulds for two-inch cubes on a glass plate and gently stirred to remove air bubbles. When the plaster was set the top was cut down level with the sides of the mold. The tests were made after the blocks had been exposed to the air for one week.

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*University Geological Survey of Kansas, Vol. V.: 163.

The blocks were crushed in a self-registering Riehlé testing machine, for the use of which we are indebted to Prof. W. F. Gilkison. They almost always broke in such a way as to leave two irregular four-sided pyramids with bases at the top and bottom. Since the test blocks were two-inch cubes, the numbers given in the table are to be divided by four to give the load per square inch, but this is not exact, because the compressive resistance of large blocks is greater per square inch of surface than for small ones.*

As shown by the table, the cement plaster is weaker the greater the proportion of sand, although individual variations in the strength of the blocks even made out of the same mixture obscure the relation. The addition of 25 percent sand reduces the strength about 15 percent, and each additional 25 percent of sand decreases the strength some 5 percent more.

Cements and mortars can be tested for their resistance to tension or compression strains. Both are important, but the compression tests are not commonly made on account of the greater difficulty and expense. Of the two, the determination of the compression strength is preferable in the case of mortars* and is of more interest, because so few of such tests are on record. The tensile strength of a cement is supposed to be one-tenth its compression strength.

In these tests Laramie cement plaster without retarder was used.

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*Behrmann. Rigaer Ind. Leitz., 1899, 25.27, in Jour. of Soc. of Chem. Ind., 1899, 18.918.

TABLE I. *The Effect of Sand on the Strength of Cement.*

Cement Parts by Weight	Sand Parts by Weight	Water Parts by Weight	Crushing Strength of 2-inch Cubes Lbs.	Average Crushing Strength of Each Set of Tests Lbs.
100	0	56.0	5730	5435
			4780	
			5430	
			5810	
100	12.5	56.0	5350	5430
			5570	
100	25	57.0	4410	4575
			4930	
			5350	
			4460	
			4310	
			4580	
			4330	
			4730	
			4360	
			4290	
100	50	58.7	4380	4378
			4440	
			4470	
			4490	
			4110	
100	75	60.0	4390	4317
			4010	
			4590	
			4310	
			4100	
			4290	
			4530	
100	100	61.2	3520	3755
			3490	
			4250	
			3890	
			3930	
			3550	
100	125	62.5	3910	3505
			3220	
			3140	
			3270	
			3760	
			3880	
			3360	
100	150	63.7	3230	3341
			4010	
			3610	
			3190	
			3160	
			3170	
			3190	
			3190	
100	175	65.0	3740	3523
			3230	
			3450	
			3450	
			3790	
			3480	

RETARDERS AND ACCELERATORS.

The setting of plaster of Paris is the reverse process of its manufacture. The plaster, $2CaSO_4.H_2O$, takes up three molecules of water and forms gypsum, $2CaSO_4.4H_2O$. The water first dissolves a little of the plaster, and this crystallizes out from the solution in long needles which interlace to form a compact mass. The process takes place in the course of ten to fifteen minutes for pure plaster, and the mass becomes very warm. The cement plaster, on account of the silica, alumina, lime and magnesia it contains, sets much more slowly and the heat given off is very slight. The process of setting is much the same as in the case of Portland cement, in which we have, however, calcium silicate instead of sulphate.

For ordinary plastering the cement plaster sets too quickly and it is always necessary to add some substance which will keep it workable long enough to use up a batch as mixed and to allow time enough for finishing off a convenient portion of the wall. This time varies according to the use made of it and the habits of the workmen, and it is customary to make up each lot of cement plaster to order when it is known exactly what is wanted.

An immense number of different kinds of retarders have been invented and patented.* They are all, however. very much alike in composition and consist essentially of some organic matter of a gluey nature. All colloids, such as glue, molasses, blood, starch, etc., retard the setting, and crystalloids (salts which crystallize well) accelerate it.

The action of retarders is probably to keep the molecules of dissolved gypsum from uniting together in crystals, as it is well known that the presence of any inert substance in a solution hinders the formation of a crystalline precipitate, and the crystals formed are smaller under such circumstances. If this is true, a retarder must weaken the plaster, because its strength depends on the inter-locking of the gypsum crystals. In all of our experiments we have found that this is the case. From Table IV it will be seen that the addition of 2 pounds per ton, or 0.1 percent of Wymore retarder to Laramie cement plaster reduced the compression strength 25.2 percent, and on Red Buttes cement plaster 2 pounds per ton weakened it 19.6 percent, and 4 pounds per ton 27.6 percent of its original strength. The use of 8 or 10 pounds per ton prevents setting altogether, and the cement remains soft and crumbly. In this case the calcium sulphate takes up the water of crystallization just as before, but the crystals formed are small and separate, and the whole mass is like chalk. It is apparent, then, that it should be the object of the manufacturer to use as little retarder as possible, both on account of its cost and because it weakens the plaster. It would be interesting to test a large variety of substances suitable for retarders to see whether they all act equally in diminishing the strength.

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*See list in University Geological Survey of Kansas, Vol V. p. 114.

In the experiments reported in Table II a number of retarders were used to see how they compared in the time they delayed the set. In Nos. 4-8, the retarder used was manufactured in Wymore, Neb., from the tankage from a packing house mixed with limestone. It is of a buff color and has only a slight odor. In 9-12, a retarder from Webster City, Iowa, was used which seems to be the same. The retarder from Swift & Co., Chicago, is of a yellowish brown color, coarsely ground, and has a strong odor. The retarder from Swift & Co., Kansas City, is very course, containing hair, fiber, bone, gravel, etc., very dark in color and has a very strong and disagreeable odor. The odor of wet cement plaster mixed with the last two retarders is so strong and disgusting that it is difficult to market plaster containing them, although the odor disappears from the walls after a few days.

An effort was made to obtain a cheap and home-grown retarder, and with this in view the cactus which grows so abundantly on the Laramie Plains (*Opuntia platycarpia*) was dried and ground.. The common malva (*Malvastrum coccineum*) was prepared in a similar manner, using the whole plant. Both these were of a light green color and with no odor but that of hay. These were found to be excellent retarders, nearly as strong as any on the market. Two pounds per ton retards the setting sufficiently for practical purposes. It is noticeable, however, that a larger amount does not lengthen the time as much as in the case of the other retarders.

Clay (Wyoming Bentonite) and dry glucose are also included, since they act as retarders.

In making the tests the finely ground retarder was accurately weighed and thoroughly mixed with the dry cement. Water was then added and the cement put on a glass plate in a cake four inches in diameter. Two needles, both a twelfth of an inch in diameter, were used to determine the time of set. One was loaded with a weight of a quarter of a pound and the other four pounds.. The time when the lighter needle ceased to make a decided impression on the cake is reported as "first setting," and when the heavier needle was supported without indentation is given as "hard set." This method gives results that are comparable with each other, though the time given is not necessarily the same as in actual use, because stirring and pressing the plaster as in using it on walls or for mortar hastens the setting very much.

Laramie cement plaster, Red Buttes cement plaster, agatite, and Red Buttes stucco (plaster of Paris) are included in the tests.

In the case of market samples the amount and kind of retarder is not stated. For these samples, as well as for the information they have given us, we are much indebted to Mr. Wm. McClary, superintendent of the Standard Cement Plaster Works, and Mr. J. B. Arthur, secretary of the Consolidated Plaster Company.

TABLE II *Effect of Retarders on Time of Setting.*

No.	Cement	Retarder	Pounds Retarder Per Ton	First Setting H. M.	Hard Set H. M.	Remarks
1	Laramie	. . . .	0	2:25	3:45	. . . .
2	"	Market sample	Undet.	4:40	5:35	. . . .
3	"	" "	"	. . . .	12:00	. . . .
4	"	Wymore	1	5:20	6:20	. . . .
5	"	"	2	6:05	7:10	. . . .
6	"	"	4	8;40	10:55	. . . .
7	"	"	6	9:50	11:30	Cracked a little
8	"	"	8	13:05	. . . .	Never harden'd
9	"	Webster City	2	5:50	6:30	. . . . [what
10	"	"	4	8:55	10:45	Cracked some-
11	"	"	6	12:15	. . . .	Cracked badly
12	"	"	8	12:35	. . . .	Did not set
13	"	Swift, Chicago	1	4:20	5:10	. . . .
14	"	" "	2	4:25	5:10	. . . .
15	"	" "	4	4:40	5:15	. . . .
16	"	" "	6	4:50	5:20	. . . .
17	"	Swift, Kansas City	1	. . . .	5:10	. . . .
18	"	" " "	2	3:35	4:10	. . . .
19	"	" " "	2	4:15	5:15	. . . .
20	"	" " "	4	4;10	5:15	. . . .
21	"	" " "	4	4:15	5:10	. . . .
22	"	" " "	6	4:10	5:00	. . . .
23	"	" " "	6	3:35	4:15	. . . .
24	"	Cactus	2	4:05	4:45	. . . .
25	"	"	2	4:35	5:20	. . . .
26	"	"	4	4:10	5:10	. . . .
27	"	"	6	4:50	5:40	. . . .
28	"	Malva	2	4:05	4:55	. . . .
29	"	"	4	4:40	4:55	. . . .
30	"	"	6	4:35	5:10	. . . .
31	"	Glucose	6	4:50	6:15	. . . .
32	"	Clay	6	4:00	5:20	. . . .
33	"	"	10	4:20	5:30	. . . .
34	Red Buttes, stucco	. . . .	0	:30	:50	. . . .
35	" " "	. . . .	0	:24	:42	. . . .
36	" " "	. . . .	0	:20	:32	. . [Cracked
37	" " "	Wymore	8	4:30	. . . .	Did not set.
38	" " "	"	2	1:00	1:45	. . . .
39	" " plaster	. . . .	0	:50	1:20	. . . .
40	" " "	Wymore	2	4:45	5:45	. . . .
41	" " "	"	8	8:25	. . . .	Soft & cracked
42	" " "	Market sample	Undet.	5:10	6:15	. . . .
43	Agatile	Market sample	Undet.	4:00	5:05	. . . .

TABLE III. *Effect of Accelerators on the Time of Setting.*

No.	Cement	Accelerator	Pounds per ton	First Setting	Hard Set
1	Laramie	....	0	2:25	3:45
2	"	Salt	6	:55	2:30
3	"	Sodium Sulphate	6	2:30	2:50
4	"	Sodium Carbonate	6	2:25	2:50

Accelerators are, of course, not needed in cement plaster, but it is important to know what substances and conditions shorten the time of setting. From Table III it appears that common salt, sodium sulphate (glauber salt), and sodium carbonate (sal soda) all accelerate the time of final setting, and the effect of salt is very decided. A sample of Laramie gypsum earth taken in 1898 contained 3.25 percent sodium sulphate, but that is not found in the material now used.

Of most importance among the accelerators is gypsum itself. If new plaster is mixed in boxes not thoroughly cleaned from the old plaster, it will set so quickly that it is difficult to work. A very small proportion of plaster already set will produce a marked effect.

The use of a large amount of water will delay the setting somewhat. Warm water hastens the setting very much.

In the manufacture of cement plaster the retarder should be thoroughly mixed with the cold plaster. If it is mixed with the hot plaster just as it comes from the kettle, as is done in some factories, it is partly melted and unequally distributed. Ten pounds per ton mixed in this way does not have so great an effect as two pounds mixed cold.

For comparison we have reported in Table IV a variety of tests on the different cement plasters, including stucco, of which we had samples. It will be seen that what has been said of the weakening effect of sand and retarders holds good for all the brands tested. The crushing strength of the three kinds of cement as marketed, with about same time of setting, is as follows:

Red Buttes cement plaster, without sand	5200
Laramie cement plaster, without sand	4065
Agatite cement plaster, without sand	3550

The Red Buttes plaster contained numerous soft spots where the plaster did not set, owing to imperfect burning. These were not found in the Laramie and agatite plasters.

Since plaster is often mixed by bulk instead of weight, it was necessary to determine the relation between the weights and measures, and the figures may be of use to others. Although the individual particles of plaster are heavier than water, yet a bushel weighs 64 pounds, or 95 percent as much as a bushel of water. A block of the cement plaster after it is set and dry, containing 50 parts sand per 100 parts of plaster, has a specific gravity of 1.5 compared with water. A cubic foot weighs 93.5 pounds. The sand used had a specific gravity of 1.5 and a ten-quart bucket holds 29.5 pounds.

Wyoming Agricultural Experiment Station.

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*Resigned to accept chair of agriculture in the Colorado Agricultural College, Fort Collins, Colorado. Prof. Luther Foster, M. S. A., of Logan, Utah, elected to fill vacancy.

TENTH ANNUAL REPORT

. . . OF THE . . .

WYOMING AGRICULTURAL EXPERIMENT STATION.

I hereby submit the tenth annual report for the Wyoming Agricultural Experiment Station, in compliance with congressional enactment. The report covers the work of the station during the fisctl year ending June 30, 1900.

ORIGIN AND PURPOSE.

The Wyoming Agricultural Experiment Station is the department of research of the College of Agriculture of the University of Wyoming. Congress in 1887 appropriated $15,000 annually for this purpose, and on January 10, 1891, the Wyoming legislature authorized the University of Wyoming to receive this appropriation. The work of the station is to aid in the acquiring and diffusing among the people of the United States, and especially of Wyoming, useful and practical information on subjects connected with agriculture, to conduct scientific investigations and experiments on the physiology of plants and animals; to investigate animal and vegetable diseases and parasites; to chemically analyze soils and water and vegetable and animal products; to acclimate grains and grasses fruits and vegetables, to our arid climate and high altitude; to ascertain the best methods of irrigation, and of retaining the moisture in the soil; to find the best breeds of stock, and the best varieties of field and garden crops for the various portions of Wyoming; and to carry on any other experiments which promise to benefit our agricultural and grazing interests. The results of these experiments are published in the station bulletins, which are sent free upon request to residents of this state.

BULLETINS.

Five bulletins have been published during the fiscal year 1899-1900. These bulletins contain pupular accounts of the results of such of the investigations by the station as were considered of especial value to our farmers and ranchmen. Such of the technical work as could be prepared is published as part of this report. The detailed accounts of scientific investigations are: "The Cryptogams of Wyoming," "Alkali Studies V," "Variety Tests With Wheat, Oats and Barley," "Some Wat‹ Measurements," Forage Plants," "Germination of Wheat and Oats Treated for Smut," and "Meteorology for 1899." The bulletins are:

No. 41. Some Experiments With Subsoiling.

This bulletin gives a general account of subsoiling and the supposed effect of subsoiling on the conservation of moisture for the growth of crops. An experiment which was conducted three years at Laramie, two years at Lander and Sheridan and one year at Wheatland and Sundance is reported, except the work at Lander, records of which were lost in transit. The results indicate that subsoiling will pay for root crops but is of doubtful value in raising grain, and that such preparation of the land does not result in a saving of moisture or decrease the necessity of irrigating crops in this region.

No. 42. Some Native Forage Plants for Alkali Soils.

A general review of the range areas of the state is given and the need of more abundant forage on alkali plains is pointed out. Seven of the native Salt or Sweet Sages are described and illustrated with notes regarding the abundance and value of each species. Three grasses, winter fat and one bulrush, which thrive in strong alkali ground, are also discussed. The bulletin shows that the plants are promising species to be brought under cultivation and especially for planting on alkali portions of the farm.

NO. 43. ALFALFA AS A HAY CROP.

This report gives a brief history of alfalfa, and instructions for its culture in Wyoming, especially at high altitudes where it has been thought practicable to grow it. The results of nine years' experiments by the Wyoming Station are reported, giving the yield of hay in several parts of the state and an account of the comparative merits of the New Turkestan variety. Accounts are given of the winter killing of alfalfa and the apparent cause; the value of alfalfa for alkali soils, and of the enemies of alfalfa so far observed in the state. The duty of water with fifteen measurements made by the station on alfalfa are also reported, and accounts are given of the success obtained with alfalfa by ranchmen who have tried it on the Laramie plains.

NO. 44. ALFALFA AS A FERTILIZER.

This bulletin discusses the need of nitrogen fertilizers for arid soils and the relation of alfalfa to the nitrogen problem, as well as its effect on the physical condition of the soil. An experiment carried out by the station to show the value of alfalfa as a fertilizer is reported. It shows that the value of alfalfa hay taken from the land was as great or greater than the value of other crops produced on an adjoining plat of the same size, and when plowed under the alfalfa having grown on the land increased the value of wheat $8 to $12 per acre, oats $16 per acre and potatoes $16 per acre, at no cost for fertilizing the land in this manner.

No. 45. A PRELIMINARY REPORT ON THE ARTESIAN BASINS OF WYOMING.

After a brief introduction setting forth the primary objects of the bulletin, a considerable space is given to a resumé of Wyoming geology. In this resumé an attempt has been made to bring the subject of geology within the reach of the people of this state, that they may utilize the data in looking up and studying artesian conditions. Each formation is briefly discussed, and with the prominent formations there are illustrations showing the fossils that are usually found in the various horizons. Each formation is also considered from an artesian standpoint Some space has been given to the discussion of water-bearing zones, and accompanying this is a table of analyses showing the kinds of water that have been found in some of the zones, and further a tabulated statement showing the general character of the water found in the various formations. Artesian wells are mentioned and there is a list of the known wells in Wyoming up to the present time. Instructions are given for the location of artesian wells. Following these topics are discussions of the various artesian basins. The state has been subdivided into eleven artesian basins, and each of these is briefly described and their artesian possibilities discussed. There are also numerous geological sections to illustrate the structure of the various basins and a geological map showing the position of the basins and the geology of each. The bulletin is illustrated with fourteen plates and fifteen geological sections. While the artesian possibilities are great in Wyoming, the present development does not in any way indicate the true conditions. A few small wells have been drilled in widely separated localities; but none of these have been carefully located; in fact, the majority of them were drilled for other purposes than securing flowing wells.

Plans of Station Work for 1900-1901.

DEPARTMENT OF AGRICULTURE AND HORTICULTURE.

1. Irrigation investigations.
    - a. Co-operation with the U. S. Department in the measurement of water on farms and in seepage investigations.
    - b. Measurements of water used on experiment farm.
    - c. Plat experiments—different amounts of water on the same crop.
    - d. Notes on sub-irrigation.
    - e. Evaporation from soil.

2. Alkali investigations.
    - a. In the field—Effect of irrigation.
      Effect of green manures.
      Economic plants on alkali soil.
    - b. In the laboratory.

3. Soil work.
    - a. Permanent soil plat—Same crop year after year.
    - b. Crops with and without summer cultivation.
    - c. Crops with aud without rotation.
    - d. Alfalfa as a soil improver.
    - e. Fertilizer—Nitrate of soda.

4. Cereals.
    - a. Treatment for grain smut.
    - b. Oats on different depth of plowing.
    - c. Plat work with grains. Best varieties of oats and wheat.

5. Forage crops.
    a. Cultivated and native, including the co-operative plats with the U. S. Department of Agriculture.
    b. Alfalfa—Different rates of seeding per acre.
    c. Alfalfa planted with different grasses.
6. Potatoes.
    a. Different amounts of water used in irrigation.
    b. Pedigreed potatoes.
7. Horticulture.
    a. Hardy fruits at Laramie and fruit notes at Lander and Sheridan.
    b. Garden—small amount of variety work.
    c. Asparagus on alkali and good land.
    d. Native trees and shrubs.
    e. Co-operative experiment in ecology.
8. Pigs on alfafa, artichokes and pease.
9. Entomology.
    a. Honey bees at Laramie.
    b. Notes on injurious insects ,collections and exchanges.
10. Studies of wheat.

THE BOTANIST.

1. Field work upon the plants of the state continued with special reference to—
    a. Forage plants.
    b. Parasitic fungi.
    c. Edible fleshy fungi.
    d. Ornamental shrubs.
    e. Herbaceous perennials suitable for flower garden.
    f. Native fruits.
2. As for 1899, continued.
3. As for 1899, continued.

THE CHEMIST.

1. Effect of alkali on germination of seeds.
2. Analysis of soil and alkali.
3. Analysis of alkali-resisting plants.
4. Analysis of irrigation water.

THE GEOLOGIST.

1. Completion of the preliminary bulletin on the artesian basins of the state.
2. The origin of alkali.
    (1) The geological location of these salts and their relation to the various terranes.
    (2) The way alkali finds its way into the soils.
    (3) Preventing further accumulation if possible.
3. Wind erosion and its relation to soil formation in the arid districts.
4. To complete the preliminary work on the birds of Wyoming and arrange notes for publication.

THE PHYSICIST AND METEOROLOGIST.

1. Movement of alkali in soils.
2. Evaporation of moisture from the surface of soils.
3. Effects of mulching the soil to various depths on the evaporation of moisture.
4. Study of terrestrial radiation and sunshine.
5. Observation upon the direction and force of air currents at Laramie.
6. Continuation of the work of making meteorological observations and co-operating with the state and the United States weather service.

Report of Station Council.

REPORT OF THE DIRECTOR.

THE STATION COUNCIL—WHAT IT IS.—The origin and purpose of the Agricultural Experiment Station maintained by the federal government in connection with the university has already been explained on a preceding page. It is the department of research of the College of Agriculture of the University of Wyoming. Besides their regular work in the class room, our professors of agriculture, botany, chemistry, physics and geology are also members of the staff on our Station Council and are engaged along their several lines of investigation in connection with the experiment work of this government station. These five professors of natural science, together with the president of the university, who is director of the station, and the secretary of the board of trustees, who is the secretary of the station, form the Station Council. This body passes on all matters pertaining to station work in the way of experimentation and research, and its recommendations are then referred to the agricultural executive committee of the board of trustees.

All plans of work by the heads of departments are first discussed and accepted, modified or rejected by the Station Council; this system insures the co-operation of the staff of station workers and prevents scattered work and misapplied effort. Again, all bulletins published by the station are first read before the Station Council and each member is free to criticise any questionable point of fact, extravagant statement or the general arrangement of the matter; and finally the bulletin may be either adopted and recommended to the Agricultural Executive Committee of the Board of Trustees for publication, or it may be returned for revision, or be entirely rejected. Such has been the general policy governing the station since its organization; and the fact that the workers have been a unit force, and so have made a combined attack on the important agricultural problems from all sides at the same time, has contributed largely to their success heretofore.

WHAT IT DOES.—The study and research of the station are made as practical as possible, and have to do with the problems which in our opinion are of most importance to the farmers of the state. For example, the subject of irrigation and the alkali problem have been given much attention. At the present time, so far as we can we are co-operating with the Department of Agriculture at Washington in the new irrigation work being done under the direction of Mr. Elwood Mead, who has been for a number of years the efficient State Engineer of Wyoming, and is now connected with the Office of Experiment Stations. The results of our work are being published from time to time. The carefully prepared bulletins, based as they are upon as thorough work as we can do, are offered to the people with the belief that they contain nothing but reliable information, upon which the greatest dependence may be placed.

The widely scattered population of the state has made it almost impossible for the station to come into direct contact with our farmers. The farming communities are naturally located in the places most favorable to agriculture, and are sometimes separated from one another by mountain ranges and long distances; and with the funds at our command and the small number of our station workers it has so far seemed impracticable to do any general farmers' institute work. However, when the time comes that it is possible for us to engage in this kind of work, we shall be glad to undertake it; because we believe it will prove most valuable in bringing the farmers and our station into closer relation with each other. The station workers would then become better acquainted with the farmers' needs, and the information offered by the station could be better brought before the attention of the farmers.

THE FARM AND BUILDINGS.—When the station was last inspected by Dr. A. C. True, Director of Experiment Stations, Washington, D. C., he made some valuable suggestions in regard to the enlargement of our experiment farm at Laramie, in order that irrigation experiments might be more extensively carried on. Accordingly our original forty acres have since been increased by a donation of an additional eighty acres of land, with water right for the same, from the Wyoming Central Land and Improvement company. This land is presented to the station to be held so long as it is used for experimental purposes, and fills a long felt want in supplying land for irrigation on an adequate scale to furnish results of value to the arid west. This land has been fenced and forty acres plowed and putinto crops this year. The station buildings are a small five room cottage, a tool shed, and a shed used as a barn at the farm; and a barn and green-house on the university grounds. The farm is well equipped with implements and all needed machinery. The great need of the station is a good-sized barn in which to store farm implements and grain, and to provide room for threshing and winnowing of seeds indoors.

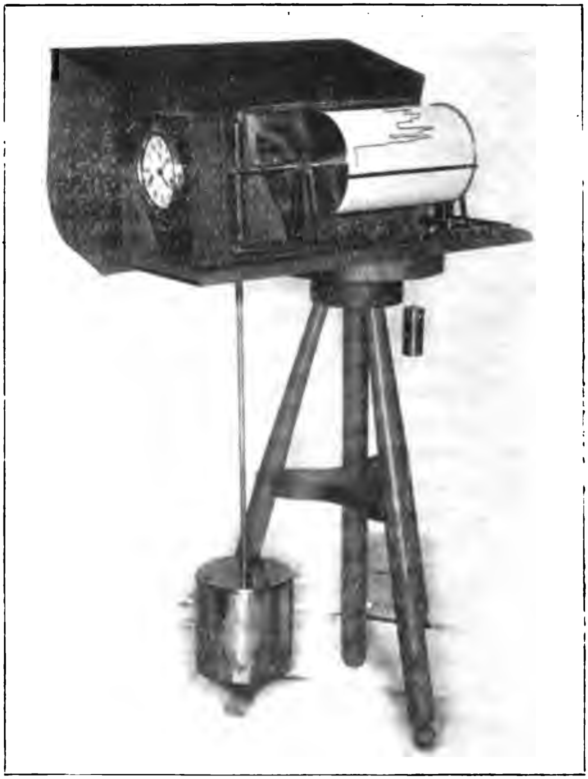
With only the amount which can be used each year for building purposes from the Hatch fund ($750) it is not possible to build more than in a very small way, and it would seem that the state will need to make some provision in the near future for more commodious buildings for the station. Particularly is this true, in case any work is begun in animal industry; it will then be necessary to add to the buildings at considerable cost. The time has come when it would seem to be necessary for us to begin to take some steps in this direction, in order to meet the demands of the stockmen in this stock-growing state. And here the Director would beg to offer the following suggestion.

When the vote of the last legislature shall have been carried into effect and the present buildings in Laramie now occupied as a penitentiary shall have been abandoned for the new state building at Rawlins, will it not be practicing a wise economy for the next legislature to turn over the old grounds and buildings in Laramie to the State Agricultural College of the University of Wyoming? And by so doing, would not the state show its good faith in receiving the generous donation from the federal government through the Hatch fund?

REPORT OF AGRICULTURIST AND HORTICULTURIST.

The bulletins issued from this department during the year were No. 41, "Some Experiments With Subsoiling;" No. 43, "Alfalfa as a Hay Crop," and No. 44, "Alfalfa as a Fertilizer." The following special papers have been prepared to accompany this report: - "Alkali Studies V," "Some Water Measurements," "Variety Tests with Wheat, Oats, and Barley," "Forage Plants," and "Germination of Wheat and Oats Treated for Smut." The work as planned for the year has been quite fully carried out. We have continued measurements of water on the station farm, and in co-operation with the Office of Experiment Stations of the U. S. Department of Agriculture, we measured the water used on the farms of Mr. C. W. Webber and Mr. J. W. Sigman. During last August I rated the Laramie river with all its tributaries and distributaries from Woods Landing, where the river flows on to the Laramie plains, to a point below McGill's ranch, where the river leaves the plains. This work was done under the auspices of the U. S. Department, and a report of the same has been made to Prof. Elwood Mead.

Enlargement of the experiment farm enabled us to inaugurate some new experiments in irrigation. Eleven acres of the new land, which lies just south of the original forty-acre plat, was set aside for investigations of the amount of water necessary to produce a maximum crop. This plat has been divided into three parts and different amounts of water applied to each. Oats were planted the first year after the sod was broken. The results of the first year's measurements have been computed and give information of much interest. During the year I completed a design for a special water register which would give larger and more accurate methods of our water measurements on the station farm. One of these registers has been manu-



factured for us by W. and L. E. Gurley, and while it did not arrive in time for the first irrigation it will be installed for other measurements of water used on small plats on the farm. This instrument records the actual depth of the water flowing over the weir and the time is represented on a scale of from one-fourth inch to one inch for each hour. The clock which turns the cylinder is provided with the ordinary clock face and hands. A glance will satisfy the observer that the position of the pen on the record sheet corresponds to the clock, which gives a double check on the time. An upright rod from the float is supplied with a sliding scale which can be set at the zero point when the water reaches the height of the base of the weir, and the position of the pen, which is attached to the cord from the float, is adjustable. This gives a double check on the position of the base line and the depth of the water flowing over the weir. These improvements, along with the increased size of the record, insure that accuracy of measurement which is so essential in scientific investigations. The accompanying illustration gives a very good idea of this special purpose register. During the year we also purchased one of the Mead water registers, and three other instruments were loaned the station from the irrigation investigation section of the Office of Experiment Stations. A Mead nilometer belonging to the station has been loaned for the co-operative experiment station exhibit at the Paris fair.

The alkali investigations have been continued during the year. The principal field work along this line has been the growth of economic plants on alkali soil. The Dwarf Essex Rape has succeeded admirably on strong alkali land. This plant is rapidly coming into favor in many sections of the country as a stock food, principally for pasturing. Mr. Fairfield, who is assistant in this department, states that his cow made regular daily visits to that part of the farm during the winter, eating the rape as long as any of it was above ground. The effect on the cream and butter, however, was decidedly unpleasant, and we would not recommend the plant as a winter pasture for milk cows. In the laboratory an experiment to show the comparative effects of sodium and potassium sulphates and chlorides on seed germination and plant growth, when the salts were present in strengths represented by equal osmotic pressures, was carried out. A report of this experiment will be found at the end of this report, published as "Alkali Studies V."

The permanent soil plat work has been continued as heretofore and in addition a field experiment on "Alfalfa as a Fertilizer," the results of which were published in Bulletin No. 44. Work with varieties of small grains was also continued. We believe the four years' tests which have been carried out with small grains have given sufficient data, and that it will be wise to reduce the work by eliminating all but the most promising varieties, which seem worthy of larger field trials. From the records Mr. Fairfield has prepared a series of tables which give the results of these trials of the varieties of wheat, oats and barley. These tables are published as a special paper in connection with this report. Some of the Russian grains furnished by the Department of Agriculture are promising for this region, especially two varieties of oats, which gave heavy yields.

The work with forage crops is resulting in data of much interest and importance. A report has been made to the Division of Agrostology on the varieties, seed of which were furnished by that Division, and a brief account of the co-operative and other work has been prepared for this report. (See "Experiments with Forage Plants.")

The fertilizer experiment with potatoes was continued last season. This was a trial with potassium chloride and sulphate, sodium nitrate, and barnyard manure for the improvement of the potato crop. So far as studied the results are negative. The previous year the salts reduced rather than increased the crop of potatoes. Without more favorable results from future trials these commercial fertilizers cannot be recommended for potatoes on the Laramie plains.

Some hardy fruits have been planted at Laramie, and the work with celery, and pedigreeing potatoes has been cantinued in a small way.

A few insects have been exchanged during the year. A special experiment with varieties of wheat at Lander and Sheridan failed at both places. At Sheridan the grains were doing well when destroyed by hail. At Lander the seed was held in the express office so long that it was too late to plant it when received and it was held over till the present season.

The sub-station farm at Lander has been rented to Mrs. Carrie B. Meyer, who pays a small cash rental and agrees to continue the experimental work with fruits as well as special trials of varieties of wheat. The Sheridan farm has been leased for one year to Mr. A. E. Baker, who also pays a small cash rental and carries on some additional experimental work. This year Mr. Baker is to report the weather observations, keep notes on the fruits and furnish such reports of the same as may be required.

The permanent improvements made on the station farm during the past fiscal year have been as follows: The general appearance of the farm has been greatly improved by laying out a drive past the principal plats and connecting the new part of the farm with the old. Some combined culverts and division gates for water have been put in across these drives and additional gates for water have been constructed for other places which improve the facilities for handling irrigation water. A storm kitchen was built on the farm cottage at a cost of about $125. Two root cellars were constructed, one in connection with the farm house for the use of the superintendent and a larger one for potatoes, at a total cost for the two of less than $25 for material. The well on the farm was sunk from a depth of 168 feet to a total depth of 300 feet. Caving material was passed through at a depth of about 210 feet, making it necessary to case the well before drilling could be continued. A supply of water was obtained, but not yet having passed through the alkali bearing formations (probably Fort Benton), the water is unfit for use. The water was analyzed by Mr. A. H. Danielson, assistant in this department, who found it to contain a total of 7.03 grams salts per liter. Of this amount 1.2 grams is Na Cl and 5.7 grams Na_2SO_4. One-half mile from the farm good water was obtained at a depth of less than 200 feet. It is probable we can obtain a good supply by going one or two hundred feet deeper than the present depth of the well.

A tool shed 32 feet by 14 feet in which to store implements was built next to the shed barn. This shed should be improved by battens over the cracks before another winter. A commodious barn building is becoming a great necessity and the present scope of the work can hardly be enlarged until some provision is made for such quarters. The permanent improvement money which can be used from the Hatch fund is so small in amount, being only five percent, or $750 each year, that little can be done with it toward a suitable building, and it seems that it will be necesary for the legislature to make an appropriation for a stock barn. So far as I know, Wyoming is the only state in which the legislature has not aided its experiment station in some such way. The live stock interests are paramount in Wyoming and should receive their share of attention by the station. Before investigation in animal industry can be taken up, it will be necesary that some additional equipment be provided. If Wyoming is to keep in line with sister states she cannot long delay making such provision. Five thousand or ten thousand dollars appropriated by the legislature would erect a suitable stock barn and provide a good water supply.

The general equipment has been increased by the purchase of the water register mentiond above; a boat which can be used for studies of seepage and studies of current meters; a Price current meter for rating streams; a new 6½ x 8½ Korona camera with Turner-Reich convertible lens; a Deering horse rake for the farm; hayfork and elevated cable for stacking alfalfa; New Havana press drill; alfalfa plow; team and harness. One of the horses purchased for the farm died and another horse was obtained. Two teams have been kept very busy through the spring months. During the year a number of new books on agriculture, horticulture and irrigation have been added, and our department collection is now of considerable importance as a working agricultural library.

The work in this department has been actively pursued during the year. The general conditions of the work were quite fully stated in our ninth annual report. We have had more and better help than ever before. Mr. Fairfield has relieved me of the details of the farm work and during the winter has been active in working up crop areas and yields and transferring the day notes to crop record books. This makes them available and puts them into permanent form. The notes and records are more nearly brought up to date than ever before.

Mr. A. H. Danielson, whose services were secured last year, has made himself almost indispensable. He has ably assisted with much of the work of this department and has given considerable time to other things for the institution. He went into the field during the early part of last season to assist with the irrigation. The new farm plats and ditches have been surveyed and platted by him. Under instruction he has cared for the greenhouse work and had charge of the alkali investigations reported as "Alkali Studies V" in this report. He has computed the measurements of water and ratings made in the seepage investigations; has done much typewriting and general office work and relieved me of the larger part of the photograph work which has been done in the office for the station and to meet other demands.

The station has been fortunate in retaining the services of sued are numbers VIII to XII of the series in the Bulletin of the Torrey Botanical Club, entitled "New Plants from Wyoming." There have also been issued during the year, papers as follows: In Erythea (July), "New Species in Oreocarya and Its Allies;" in Botanical Gazette (Aug.), "Some Species of Tetraneuris and Its Allies;" (Dec.), "Some Rocky Mountain Chyrsothamni;" (Feb.), "A New Violet;" in the Plant World (Mar.), "Popular Ignorance Concerning Botany and Botanists; in Asa Gray Bulletin (April), "Notes Upon the Flora of Yellowstone Park."

One bulletin, No. 42, "Some Forage Plants for Alkali Soils," has been issued from this department.

The investigation of the native fungi, which has had some attention for the past few years, has resulted in the accumulation of a collection upon which may be based a preliminary report. While the collection is far from complete, it gives a fair idea of what parasitic forms flourish under the climatic conditions which previal in this state. Believing that it might be of interest, the other Cryptogams are also included in the annotated list which is published as part of the tenth annual report of the experiment station.

REPORT OF THE CHEMIST.

Most of the work during the year has been the continuation of the study of the effect of alkali on plant life. The previous experiments showed that an important factor in the retardation of the germination of seed caused by alkali was the osmotic pressure of the solution of salts in the soil, and the investigations carried on this year proved that osmotic pressure has the same effect on growing plants.

A number of analyses of soils and alkalies were made during the year and a series of analyses of the water of the Laramie river was made for the Department of Agriculture to determine the increase in alkali content and accumulation of silt by the passage of the river through the Laramie plains.

REPORT OF THE GEOLOGIST.

During the past four summers I have paid special attention to the artesian basins in Wyoming, and as a result of this work I have finished a bulletin entitled "A Preliminary Report on the Artesian Basins of Wyoming. This bulletin comprises about 200 pages, is well illustrated and is also accompanied with a geological map. The map not only portrays the geology of the state but also gives the location of the artesian basins.

In adidtion to my other duties I have spent considerable time in studying and collecting birds. I have on hand at the present time, ample material to publish a bird bulletin. Our collection numbers between 400 and 500 skins. I have secured all of the publications that I can find relating to Wyoming birds and have also collected all other valuable data. The number of birds known to Wyoming is nearly 300 species. The bird bulletin can be published as soon as ordered.

The work on the origin and geological occurrence of alkali in Wyoming has received some attention; but not enough data has been collected to warrant the publication of a bulletin.

For a number of years I have carried on the study of wind erosion and its relation to soil making. These data have been secured while doing other work in various parts of the state. I hope to secure sufficient information during the coming summer to warrant the publication of a bulletin during the year 1901.

My field work for this summer will include the study of wind erosion and its relation to soil making, and the origin of alkali and its geological occurrence.

REPORT OF THE METEOROLOGIST AND PHYSICIST.

Observations in the Meteorological Department have been taken of the relative humidity, maximum and minimum temperatures, pressure of the air, rainfall, snowfall, velocity and direction of the wind, evaporation, percentage of sunshine, and temperature of the soil at various depths. All observations, except amount of rainfall and snowfall, are taken each day at 7 a. m. and 7 p. m.

In the Department of Physics the following are some of the problems which are being investigated as rapidly as circumstances will permit:

Movement of alkali in soils.

Evaporation of moisture from the surface of soils.

Effects of mulching the soil to various depths on the evaporation of moisture.

Study of terrestrial radiation and sunshine.

The following were the most important pieces of apparatus purchased during the year: Sixteen galvanized iron tubes, a portable lantern stand, opaque screen, straight-line diffraction grating, focusing lens, parallel-beam nozzle, apparatus for showing Newton's rings, direct compound prism, photochromoscope, polariscope, model of pendulum clock, two sets of gramme weights, Barker's mill, labial whistle with movable membrane, refraction apparatus, Melonie's apparatus, thermopile, electroscope, apparatus for electrolysis, three Crook's tubes, manometer, twelve burettes, fourteen nests of beakers.

Treasurer's Report.

UNIVERSITY OF WYOMING,
AGRICULTURAL EXPERIMENT STATION,
LARAMIE, WYOMING,
. . . In Account With . . .
THE UNITED STATES APPROPRIATION, 1899-1900.

DR.

To receipts from the Treasurer of the United States as per appropriation for fiscal year ending June 30, 1900, as per Act of Congress approved March 2, 1887	$15,000.00	

CR.

By Salaries		$ 2,875.00
Labor		5,032.76
Publication		1,143.53
Postage and stationery		383.08
Freight and express		316.81
Heat, light and water		932.02
Chemical supplies		423.58
Seeds, plants and sundry supplies		592.57
Feeding stuffs		22.00
Library		64.09
Tools, machinery and implements		363.17
Furniture and fixtures		387.44
Scientific apparatus		485.58
Live stock		300.00
Traveling expenses		986.30
Contingent expenses		40.82
Building and repairs		750.00
Total	$15,000.00	$15.000.00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the University of Wyoming Agricultural Experiment Station for the fiscal year ending June 30, 1900; that we have found the same well kept and classified as above, and that the receipts for the year from the treasurer of the United States are shown to have been $15,000 and the corresponding disbursements $15,000; for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving no balance on hand.

And we further certify that the expenditures have been solely for the purposes set forth in the Act of Congress approved March 2, 1887.

Signed: S. C. PARKS,
HENRY L. STEVENS,
Auditors.

[SEAL]

SUPPLEMENTARY STATEMENT.

DR.	Farm Products.	Total.
To receipts from other sources than the United States for the year ending June 30, 1900	$340.35	$340.35
CR.		
Traveling expenses	17.71	17.71
Buildings and repairs	322.64	322.64
Total		$340.35

ALKALI STUDIES, V.

By B. C. BUFFUM, M. S., and E. E. SLOSSON, M. S.

PUBLISHED AS PART OF THE TENTH ANNUAL REPORT OF THE
WYOMING EXPERIMENT STATION.

JULY, 1900.

LARAMIE, WYOMING.

SALT SOLUTIONS USED.

The salts used in the experiments were sodium sulphate and sodium chloride, and potassium sulphate and potassium chloride. A series of these solutions were made which had the same osmotic pressures. Knowing the effect produced by sodium sulphate in previous experiments, this salt was taken as the arbitrary base, using it in strengths of 0.5 percent, 1.0 percent, and 2.0 percent solutions, which are common concentrations in Wyoming alkali soils. These percents of sodium sulphate in solution gave corresponding osmotic pressures of 2.03 atmospheres, 3.80 atmospheres, and 7.10 atmospheres. The following table gives the precent of each salt used to produce the same osmotic pressure as above:

TABLE 1—*Osmotic Pressure and percent of Salt.*

Osmotic Pressure in Atmospheres.	2.03	3.80	7.10
	percent	*percent*	*percent*
Na_2SO_4	0.50	1.00	2.00
K_2SO_4	0.67	1.32	2.51
$NaCl$	0.27	0.51	0.97
KCl	0.33	0.64	1.22

GERMINATION OF SEEDS.

Wheat and alfalfa were selected as one cereal and one legume to germinate in the above solutions. Granite iron pie plates were used, in each of which was placed 850 grams of sand, which had been washed free from soluble salts. On each plate was placed a layer of sand in which the seeds were embedded. They were then covered with pieces of thin cheese-cloth, over which the remaining sand was placed.* This enabled the upper layer of sand to be removed in order to count the seeds as they germinated. To each of the plates so arranged was added 150 c. c. of solution containing the salt with osmotic pressures of about 2, 4, and 7 atmospheres as given in table I. The sand was dried, so the solution added gave 15 percent moisture to each plate. As it is the salt in solution which affects the seed or plant, there would be no dilution by the sand, i. e., the same osmotic pressure of salt would be present regardless of the amount of sand. However, the evaporation of the water from the plates would increase the strength of the salts and precautions were taken to prevent this so far as possible. They were placed in a copper germinating chamber, which was kept closed except during the time the seeds were being counted. Each plate was weighed after adding the solutions and distilled water added each day to replace that which had evaporated. One hundred seeds each of wheat and alfalfa were planted in each plate on March 28, between 3 and 4:30 o'clock p. m. The first counting of the germinated seeds was made 48 hours after they were planted. Table II gives the result with wheat and Table III with alfalfa seed. The first column gives the number of hours from the time of planting. The other columns give the number of seeds germinated in the different strength solutions of each salt.

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*A careful study was previously made of the effect of such pieces of cheese-cloth on the movement of alkali salt through the sand. Several trials in which alkali solutions were added to sand which was separated into layers by the thin muslin; allowed to stand about a week and then analyzed, showed practically no difference in the amount of alkali in any part of the sand above to below the dividing layer of cloth.

A study of the tables shows that the retarding effect of the salts on germination of wheat and alfalfa is almost identical in each series of salt solutions. There are only slight variations, such as might be expected in any two or more sets of seeds germinating under conditions which are practically the same. There is a remarkably regular decrease in the germination of the seeds as the osmotic pressure increases, but there is no apparent difference between the effect of sodium and potassium nor between sulphates and chlorides either of the same or of different salts. This strengthens the conclusion reached in previous experiments, so far as seed germination is concerned, that the retarding effect is due to the osmotic pressure of a salt rather than to the kind of salt. The strongest solution of potassium chloride apparently retarded the germination of both wheat and alfalfa seed less than the same strength of the other salts used, but the difference is only slight and can not be taken as conclusive evidence that this salt does not produce the same general effect.

TABLE II—*Germination of Wheat.*

Percent of seed germinated.

Salt	None H_2O	Na_2SO_4			Na Cl			K_2SO_4			K Cl		
Pressure in atmospheres	00	2.03	3.80	7.10	2.03	3.80	7.10	2.03	3.80	7.10	2.03	3.80	7.10
Hours													
48	94	91	81	44	91	89	43	89	84	25	91	86	73
72	98	93	93	90	99	92	87	96	94	88	94	89	95
96	99	98	96	94	100	93	95	96	96	94	96	91	95
120			97	95		95	96	97		98	97	92	97
144				96		97			97			94	
168			98										98
209													
260													

TABLE III.—*Germination of Alfalfa.*

Percent of seed germinated.

Salt	None, water	Na_2SO_4			Na Cl			K_2SO_4			K Cl		
Pressure, atmospheres	0.0	2.03	3.80	7.10	2.03	3.80	7.10	2.03	3.80	7.10	2.03	3.80	7.10
Hours													
48	86	70	36		87	75	14	79	66	12	88	78	52
72	98	88	89	28	94	94	74	94	93	88	96	91	92
96		96	97	75	97	98	99	97	97	96	98	97	98
120		97	98	81			100				99		99
144			99	91						97			
168				94									
209				96									
260													

As in the experiments previously published, the effect of salts in solution is to retard the time of germination. The percentage of seeds finally germinated in the salt solutions is as great as in pure water. The retardation of some five or six days may appear of no practical importance, but the growing season is so short at high altitudes that even a few days may make the difference between a crop and a failure.

GROWTH OF WHEAT AND ALFALFA IN SODIUM AND POTASSIUM SALTS OF THE SAME OSMOTIC PRESSURE.

The same solutions were used as in the germinating test reported above. The plants were grown in clean river sand free from soluble salts and enough solution added to make fifteen percent moisture present. When saturated, this sand held eighteen percent water. The sand was analyzed for potash and found to contain 3.566 precent K_2O, none of which is supposed to be available to plants.

POTS.—Previous attempts had demonstrated that it was not feasible to use alkali salts in porous pots, as the evaporation of water left the pots incrusted with salts, which left unknown quantities of salts in the soil.* Plants are not apt to succeed well if grown in pots which have no drainage or ventilation. Inquiries were made of Prof. H. J. Wheeler of Rhode Island, who has made a study of the kinds of pots best to use for seed experiments, and we adopted his suggestion except that we used glazed earthenware pots instead of iron ones. Having made some trials, it was found that the salts used would have no appreciable effect on the glazing of the jars.

The suggestion by Prof. Wheeler, of method of ventilating the pots, was a good one. Pieces of stove-pipe iron were bent into half cylinders, and cut into lengths which would fit across the bottom of the jars. These irons were punched full of small holes, to provide drainage from the sand into them, and at each end a larger hole was made in the top, over which half inch glass tubes were placed.

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*See photograph on p. 32 of Alfalfa Studies III, Ninth An. Report.

These tubes extended up through the sand, and one of them was five or six inches longer than the other, so it acted like a chimney, producing a draft of air down the short tube and out the longer one, removing any surplus moisture collecting in the cavity produced by the iron half-cylinder at the bottom. That they were operating as they should could be seen at a glance in the mornings, as drops of condensed moisture would collect in the top of the longer tube, while the shorter one was always dry. As the water passed out in the form of vapor, all the salt was left in the pots. Each pot with its sand and solution was weighed and at intervals distilled water was added to take the place of that lost by evaporation from the air drainage, surface of the pots and transpiration by the plants.

NUTRITIVE SOLUTIONS.—After studying the nutritive solutions given by botanical authorities, the following combinations were used:

NO. 1.		NO. 2.	
For the Sodium salts.		For the Potash salts.	
KNO_3	1.0g	$Na\ NO_3$	0.8g
$Ca\ (NO_3)_2$	0.5	$Ca(NO_3)_2$	0.5
$Mg\ SO_4$	0.5	$Mg\ SO_4$	0.5
Bone Meal	2.0	Bone Meal	2.0

In No. 2 less of the sodium nitrate was used than of the potassium nitrate in No. 1, because the sodium nitrate has a greater osmotic pressure and the attempt was made to make them of as nearly the same pressure as possible. Instead of calcium phosphate or acid potassium phosphate, 2 grams of raw bone meal was used in each solution, as the bone meal contained the phosphates and a small amount of organic nitrogen as well.

The above amounts of nutritive salts were added to the five kilograms of sand in each of the pots. To the nutritive solution was added the percents of salts which would

PLATE I.

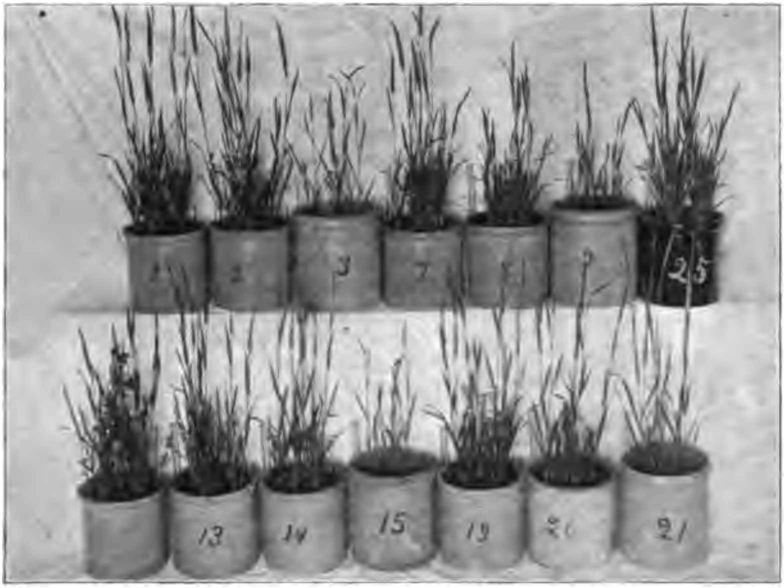

FIG. 1. Wheat, in alkali solutions, June 10, 1900.

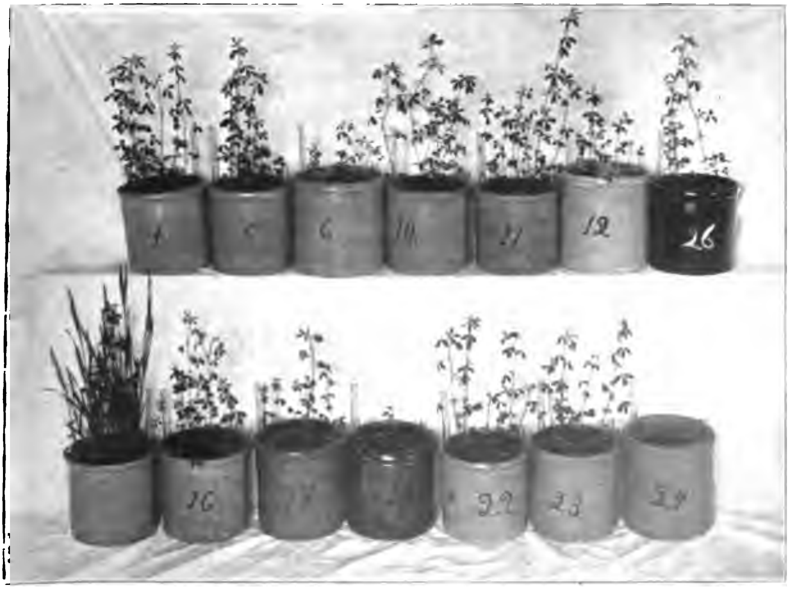

FIG. 2. Alfalfa, in alkali solutions, June 10, 1900.

PLATE II.

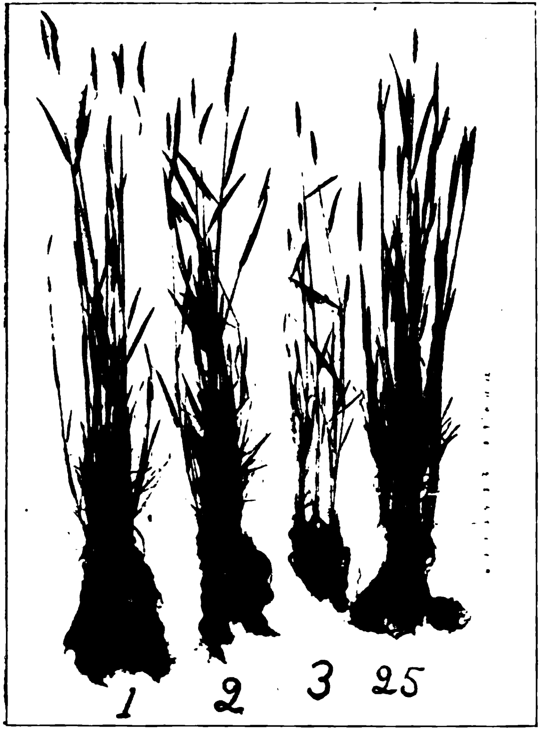

FIG. 3.—WHEAT.

No. 1.—Grown in Na_2SO_4 of 2.03 osmotic pressure.
No. 2.—Grown in Na_2SO_4 of 3.80 osmctic pressure.
No. 3.—Grown in Na_2SO_4 of 7.10 osmctic pressure.
No. 25.—Grown in check of 0.00 osmotic pressure.
Scale in inches on the right.

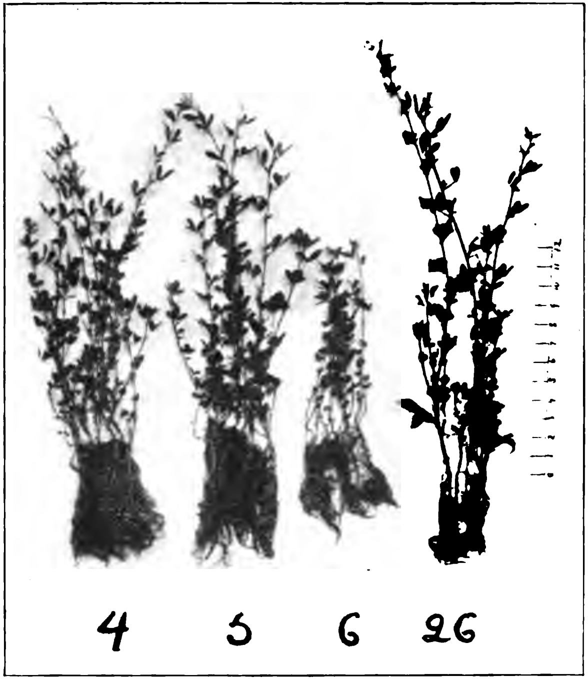

FIG. 4.—ALFALFA.

No. 4.—Grown in Na_2SO_4 of 2.03 osmotic pressure.
No. 5.—Grown in Na_2SO_4 of 3.80 osmotic pressure.
No. 6.—Grown in Na_2SO_4 of 7.10 osmotic pressure.
No. 26.—Grown in check of 0.00 osmotic pressure.
Scale in inches on the right.

PLATE III.

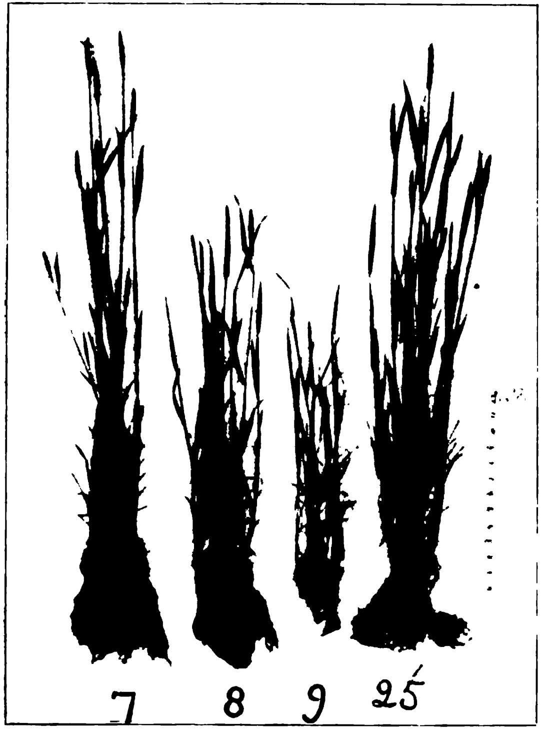

FIG. 5.—WHEAT.

No. 7.—Grown in K_2SO_4 of 2.03 osmotic pressure.
No. 8.—Grown in K_2SO_4 of 3.80 osmotic pressure.
No. 9.—Grown in K_2SO_4 of 7.10 osmotic pressure.
No. 25.—Grown in check of 0.00 osmotic pressure.
Scale in inches on the right.

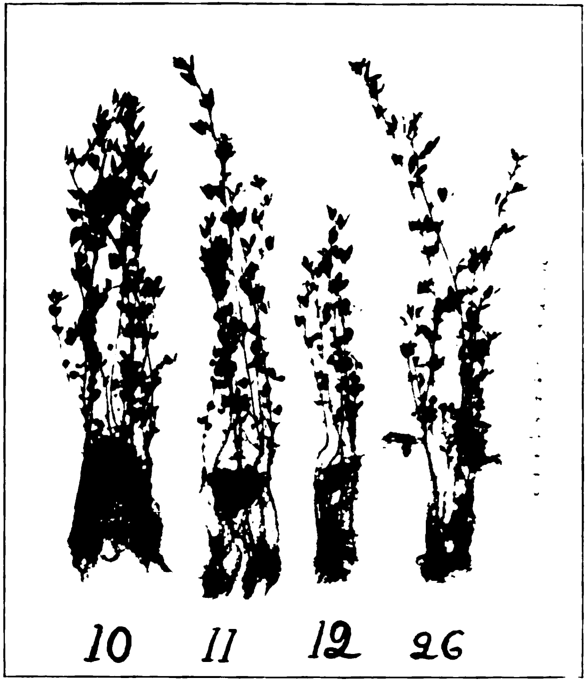

FIG. 6.—ALFALFA.

No. 10.—Grown in K_2SO_4 of 2.03 osmotic pressure.
No. 11.—Grown in K_2SO_4 of 3.80 osmotic pressure.
No. 12.—Grown in K_2SO_4 of 7.10 osmotic pressure.
No. 26.—Grown in check of 0.00 osmotic pressure.
Scale in inches on the right.

PLATE IV.

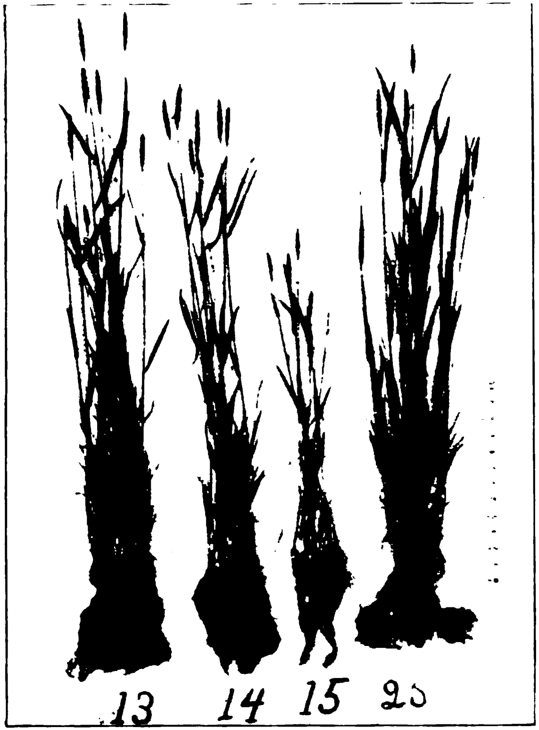

FIG 7.—WHEAT.

No. 13.—Grown in Na Cl of 2.03 osmotic pressure.
No. 14.—Grown in Na Cl of 3.80 osmotic pressure.
No. 15.—Grown in Na Cl of 7. 10 osmotic pressure.
No. 25.—Grown in check of 0.00 osmotic pressure.
Scale in inches on the right.

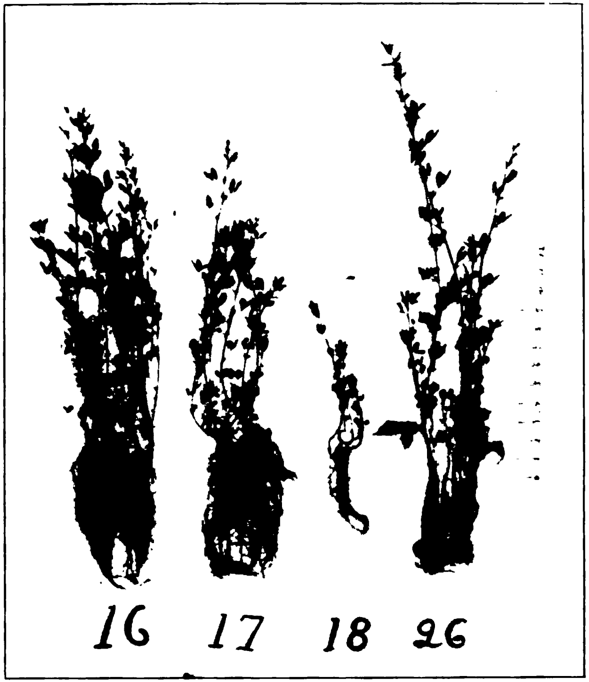

FIG. 8.—ALFALFA.

No. 16.—Grown in Na Cl of 2.03 osmotic pressure.
No. 17.—Grown in Na Cl of 3.80 osmotic pressure.
No. 18.—Grown in Na Cl of 7.10 osmotic pressure.
No. 26.—Grown in check of 0.00 osmotic pressure.
Scale in inches on the right.

PLATE V.

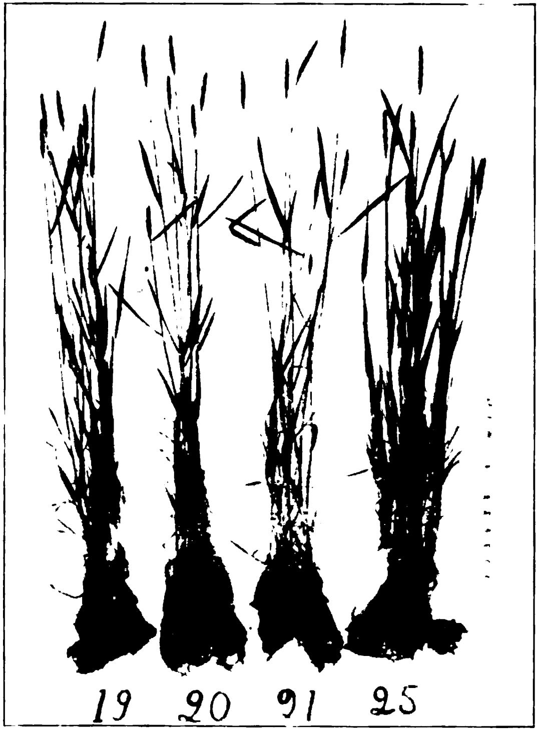

FIG. 9.—WHEAT.

No. 19.—Grown in K Cl of 2.03 osmotic pressure.
No. 20.—Grown in K Cl of 3.80 osmotic pressure.
No. 21.—Grown in K Cl of 7.10 osmotic pressure.
No. 25.—Grown in check of 0.00 osmotic pressure.
Scale in inches on the right.

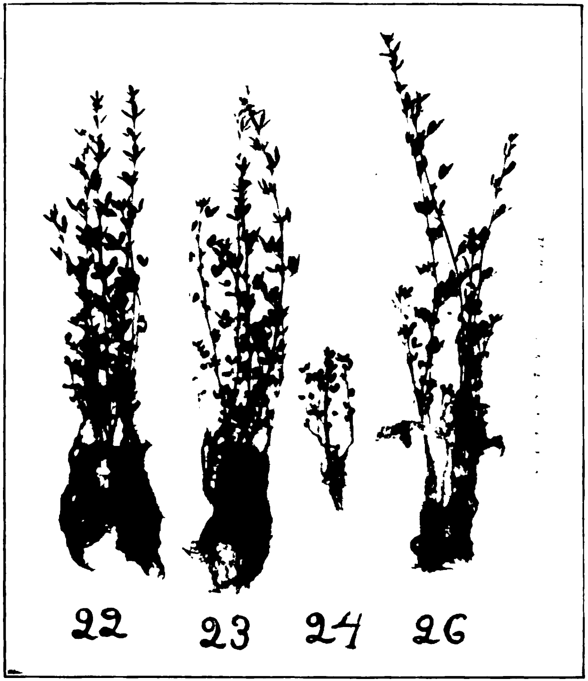

FIG. 10.—ALFALFA.

No. 22.—Grown in K Cl of 2.03 osmotic pressure.
No. 23.—Grown in K Cl of 3.80 osmotic pressure.
No. 24.—Grown in K Cl of 7.10 osmotic pressure.
No. 26.—Grown in check of 0.00 osmotic pressure.
Scale in inches on the right.

produce the different osmotic pressures, so the pressure was increased above the computed amount by the pressure of the nutritive salts added, but the increase of pressure due to the nutritive solution is too small to take into consideration. Enough of the combined solution was made up for each pot to give fifteen percent moisture. Two check pots were supplied with nutritive solution and water only and one was given double the amount of nutritive solution as an indication of whether the right amount of nutrition was supplied. About fifteen seeds of wheat were planted in each of one series of pots and twice as many seeds of alfalfa in the other series, which contained the same strengths of the salts being studied. The seeds were planted March 22, between 3 and 4 o'clock p. m.

In the pots which contained double the amount of nutritive solution the wheat and alfalfa were allowed to grow together. This is the pot not numbered shown on the left and at the bottom of Figs. 1 and 2, Plate I. The plants grew no better than those which had only the single strength of nutritive salts. See pots No. 25 and No. 26 in the same illustration.* On April 7, after the plants came up and had developed the first two leaves, the weaker ones were pulled out, leaving only six plants in each pot. In one or two instances a seed which was slow in coming up developed later, which accounts for seven stools in some of the pots at the time they were harvested.

The illustrations, Plates II to VI, show the comparative growth of the plants at the time they were harvested on June 25. Tables IV and V give the numbers of the pots, the corresponding osmotic pressures in atmospheres, and comparative notes on growth, and weight of plants harvested, both green and dry matter, and Table VI gives the sulphates and chlorides taken up by the plants in each case.

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*Photograph from which Plate I was made was taken June 10.

From the standpoint of the modern theory of solutions, however, the whole question of the action of fertilizers must be restudied both experimentally and theoretically. We now know that the absorption and movement of food material in the plant is largely controlled by osmotic pressure and that some of the cell walls act like semi-permeable membranes permitting the free passage of water but preventing or hindering the passage of salts and other matter in solution. A substance dissolved in water acts just like a gas. It tends to expand, that is, to increase the space it occupies. This may be done in two ways. If nothing prevents , the substance in solution spreads through the whole liquid until it is evenly diffused. If a semi-permeable membrane prevents the passage of the dissolved substance through all the water, it may still expand if water can be drawn through the membrane, thus enlarging the space which it can occupy. If this is prevented a pressure on the membrane results, the osmotic pressure, which is identical in nature and amount with gas pressure. Solutions always tend toward homogenety, either by the dissolved substance passing from parts of greater concentration to those of less or by the solvent moving in the reverse direction.

In the previous experiments of this series it was shown that the absorption of water by seeds was hindered by the osmotic pressure of the solutions in which the seeds were placed, that various salts and sugar in widely different amounts produce the same effect if their osmotic pressure was the same and that seeds in which the power of germination had been destroyed and even wood were affected in the same way as living seeds. The present experiments extend the study to germination and the growing plant, and it appears that the osmotic pressure of the solution in which the plant is placed tends to prevent its growth by hindering the absorption of water. This effect is so great as to entirely overshadow the nutritive action of the different salts and excess of potash salts is shown to be quite as bad as excess of sodium salts.

As the experiment had a practical aim, the study of plant growth in the arid regions, the conditions were chosen to imitate those found in nature and are not such as would otherwise have been selected in a purely scientific study in plant physiology. In the soils of the arid region we have, as we have in these pot experiments, a nutritive solution containing all the necessary plant foods but accompanied with a large excess of some particular salt, usually sodium sulphate, magnesium sulphate or sodium chloride. From the results given in the tables and illustrations it appears that the effect of a large excess of any salt in the soil is to hinder the growth of plants and that the osmotic pressure of the solution is an important factor in producing this result. It is not to be supposed that the effect is a simple one. On the contrary, the presence of a large excess of some salt must not only increase the osmotic pressure, but also change the conditions of assimilation of plant food in many ways and disarrange the nutritive system of the plant.

ABSORPTION OF SALTS FROM SOLUTIONS.

In order to determine in how far the salts in excess were absorbed by the plants, they were analyzed for chlorides or sulphates and the results are given in Table VI. It will be seen that in the case of both sulphates a greater amount of the salt was taken up by the plant the more concentrated the solution. In the case of the chlorides, on the contrary, the normal amount in the plant was not increased but actually diminished by the increase in the concentration of the solution. In the previous experiments on the absorption of salts by seeds no such difference between sulphates and chlorides was found and it is perhaps due to the fact that sulphur is of more importance as a plant food than chlorine.

TABLE VI.—*Salts absorbed by plants.*

No.	Plant	Salt	Percentage	Osmotic pressure, atmospheres	Percentage of salt in the air-dried plant
26.	Alfalfa	. . . .	. . . .	. . . .	.49 sodium sulphate .67 potassium sulphate
4.	"	Sodium sulphate	.50	2.03	1.49 sodium sulphate
5.	"	" "	1.00	3.80	2.33 " "
6.	"	" "	2.00	7.10	5.20 " "
10.	"	Potassium sulphate	.67	2.03	2.57 potassium sulphate
11.	"	" "	1.32	3.80	3.47 " "
12.	"	" "	2.51	7.10	5.07 " "
16.	"	Sodium chloride	.27	2.03	.41 sodium chloride
17.	"	" "	.51	3.80	.19 " "
18.	"	" "	.97	7.10	.10 " "
22.	"	Potassium chloride	.33	2.03	.28 potassium chloride
23.	"	" "	.64	3.80	.26 " "
24.	"	" "	1.22	7.10	.13 " "
25.	Wheat	. . . .	. . . .	. . . .	.83 sodium sulphate 1.14 potassium sulphate
1.	"	Sodium sulphate	.50	2.03	.80 sodium sulphate
2.	"	" "	1.00	3.80	1.90 " "
3.	"	" "	2.00	7.10	2.24 " "
7.	"	Potassium sulphate	.67	2.03	2.16 potassium sulphate
8.	"	" "	1.32	3.80	3.30 " "
9.	"	" "	2.51	7.10	14.97 " "
13.	"	Sodium chloride	.27	2.03	3.14 sodium chloride
14.	"	" "	.51	3.80	2.29 " "
15.	"	" "	.97	7.10	.80 " "
19.	"	Potassium chloride	.33	2.03	2.12 potassium chloride
20.	"	" "	.64	3.80	1.80 " "
21.	"	" "	1.22	7.10	1.71 " "

In Nos. 25 and 26, plants grown in nutritive solution alone, the sulphuric acid actually determined is calculated both as potassium and sodium sulphates for comparison.

EVAPORATION OF WATER FROM THE SALT SOLUTIONS AND PLANTS GROWING THEREIN.

Table VII gives the amount of water added to each pot to take the place of that lost by evaporation and bring it back to the initial weight, which was carefully determined at the beginning of the experiment. The amount is given in grams, each date water was added, the average amount evaporated each day being shown in the last column. The increase in the evaporation during June is due to the increased amount of water thrown off by the plants as they grew larger in size. The wheat produced more weight of plant in the nutritive solution alone than in any of the salt solutions and in every case less water was lost by evaporation and transpiration in the salt solutions. On the other hand, the alfalfa produced more weight of plant in the weaker salt solutions and more water was lost from these solutions than from the nutritive solution alone. With the exception of the wheat in K Cl solutions, there is quite a regular decrease in the amount of water evaporated as the pressure of the salt increased. This is due both to the difference in the size of the plants produced and to the increase in pressure. Averaging the amounts of water added to each pot up to and including April 11, while the plants were small and before there was marked difference in them as they grew in the several pots, gives no results from which conclusions can be drawn. In general there was greater evaporation from the check pots than from those containing salts. The loss of water by evaporation would increase the osmotic pressure of the solution remaining, so the mean strength of each solution for the entire experiment is somewhat greater than the indicated concentration of the solutions used.

Planted March 24.

TABLE VII.—*Evaporation from pots with alkali salts.*

Pot No	Salt	Plant	Strength in atmospheres	Water added March 24	March 28	March 30	April 2	April 5	April 7	April 11	April 16	April 20	Aptil 23	April 27	May 1	May 7	May 12	May 15	May 19	May 23	May 26	May 30	June 2	June 5	June 7	June 12	June 15	June 18	June 21	June 24	Total	Average per day
25	Water	Wheat	0.0	152	169	83	194	122	128	149	258	361	229	244	161	546	700	336	400	300	480	800	500	500	500	850	500	800	800	400	10662	394.9
26	"	Alfalfa	0.0	74	116	144	167	91	128	125	167	254	163	221	124	522	400	182	300	200	224	500	175	300	300	450	150	400	500	600	6977	258.4
1	Na_2SO_4	Wheat	2.03	106	125	95	160	160	58	87	184	294	183	248	158	466	533	220	366	383	343	652	454	422	576	627	580	600	700	700	9480	351.1
2	"	"	3.80	100	165	96	129	105	103	87	178	290	167	200	135	443	519	186	371	336	400	650	430	430	544	644	500	600	700	600	9108	337.3
3	"	"	7.10	143	152	68	164	126	100	64	142	242	141	158	154	220	467	166	254	215	252	478	434	200	300	400	300	120	400	400	6269	232.2
4	"	Alfalfa	2.03	100	145	73	128	100	85	86	155	204	143	177	121	300	400	135	240	218	255	600	454	300	480	450	422	500	600	620	7491	277.4
5	"	"	3.80	138	146	55	127	138	60	100	168	230	140	158	97	330	347	170	243	220	238	664	338	253	420	400	350	420	600	550	7100	262.9
6	"	"	7.10	*180	100	79	158	127	77	77	162	250	140	174	104	300	388	160	300	200	268	450	238	220	300	441	300	110	400	420	6123	226.8
7	K_2SO_4	Wheat	2.03	75	196	60	183	148	100	100	266	300	200	266	178	519	605	282	373	400	426	700	378	341	556	540	480	550	600	640	9362	346.7
8	"	"	3.80	68	227	53	153	140	94	118	189	280	175	191	118	400	478	184	242	200	342	552	359	364	335	445	400	400	550	560	7717	285.8
9	"	"	7.10	100	166	83	159	100	84	100	145	210	124	172	100	340	400	140	190	200	243	500	200	200	284	316	200	262	300	320	5638	208.8
10	"	Alfalfa	2.03	43	203	30	180	86	87	92	100	245	168	184	100	270	376	118	244	300	175	551	352	300	436	400	400	500	650	600	7190	266.3
11	"	"	3.80	60	188	76	151	105	96	102	189	246	178	178	100	300	400	176	226	200	250	500	324	350	245	329	400	400	500	470	6739	249.6
12	"	"	7.10	110	212	73	138	91	95	100	115	250	191	168	100	300	346	138	225	200	200	400	274	160	300	392	282	300	400	415	5975	221.3
13	Na Cl	Wheat	2.03	176	206	98	173	108	123	136	247	293	200	249	186	524	700	252	300	348	456	672	400	400	555	584	500	550	850	680	9966	369.1
14	"	"	3.80	50	161	74	176	106	100	136	195	290	164	216	146	400	471	200	300	325	348	600	338	248	400	500	400	500	500	600	7944	294.2
15	"	"	7.10	32	170	78	172	68	100	124	160	234	151	162	102	354	330	200	200	233	340	...	100	142	249	300	200	300	400	320	5221	200.8
16	"	Alfalfa	2.03	150	190	72	168	96	100	100	182	230	177	172	100	356	400	200	284	252	300	500	353	300	380	500	500	400	700	700	7862	291.2
17	"	"	3.80	42	160	66	150	104	80	96	150	217	146	195	100	343	340	192	278	236	237	500	300	200	300	370	300	370	420	564	6456	239.1
18	"	"	7.10	45	168	56	163	84	100	112	126	244	139	200	126	327	376	173	300	200	176	500	200	200	200	300	200	210	300	400	5625	208.3
19	K Cl	Wheat	2.03	57	148	123	200	136	123	96	238	284	200	262	100	454	541	268	300	370	288	600	423	400	420	524	500	500	700	533	8788	325.5
20	"	"	3.80	132	129	137	236	118	153	100	200	300	200	247	138	453	524	236	300	300	300	580	362	323	400	570	310	450	600	530	8328	308.4
21	"	"	7.10	176	188	136	208	176	148	158	263	200	156	254	119	500	570	292	276	285	392	661	340	349	400	500	350	400	600	600	8797	325.8
22	"	Alfalfa	2.03	85	147	108	192	98	96	116	212	279	156	196	127	400	356	177	300	188	200	488	391	264	356	500	325	484	600	700	7541	279.3
23	"	"	3.80	62	159	36	171	71	88	114	183	238	135	198	178	300	420	178	300	141	244	480	286	270	300	400	370	...	600	520	6442	247.8
24	"	"	7.10	40	182	41	186	76	82	118	144	241	173	179	147	324	400	190	300	171	200	450	200	200	260	235	300	252	250	380	5721	211.9

*48 in excess.

THE DISTRIBUTION OF ALKALI IN THE SOIL OF THE EXPERIMENT FARM.

E. E. SLOSSON.

The most difficult problem of the arid region is to irrigate without bringing out the alkali. In many places, even where the natural negation shows that there is no excess of alkali on the surface, yet there are beds of it several feet below, and when such soil is irrigated it becomes saturated with water and the alkali rises to the surface, where it is left on the evaporation of the water as a white crust. An injurious accumulation of salts on the surface may also occur through improper irrigation in cases where the total amount of soluble salts is not excessive and would be beneficial instead of harmful if properly distributed.

The movement of alkali in the soil under different methods of irrigation has been an especial subject of study on the Laramie experiment farm from the beginning. Analyses of the virgin soil have been made and the amount and composition of all the water used in irrigating is known and a record has been kept of all the crops harvested.

In continuation of this work a number of alkali determinations on different parts of the experiment farm have been made and some of them are here reported in order to put them on record for future reference. The alkali on the Laramie Plains is of the variety known as "White Alkali," consisting mostly of sodium sulphate (glauber salts), with a smalller amount of sodium chloride (common salt).

No uniform method of analyzing soils for soluble salts has been adopted, so there is a great variety of processes and ways of reporting in use and it is often impossible to compare the results of different chemists. The chief difference is in the calcium sulphate or gypsum. In almost all Wyoming soils this is present in abundance, and if the soluble salts are extracted by leaching, a large and variable quantity of calcium sulphate is obtained. If the simpler process of shaking the soil with a known amount of water and taking an aliquot part of the supernatant solution for analysis is adopted the amount of gypsum obtained depends on the quantity of water and soil used. If a complete analysis is to be made the calcium sulphate is determined and can be subtracted, but it is often desirable to run a large number of samples for total alkali alone. In these tests a simple method was used which seems to meet the difficulty. 100g. of soil was put into a glass-stoppered bottle with 200 cc. of distilled water and left for several days with occasional shaking. When it is settled a convenient quantity is drawn off with a pipette and without filtering evaporated to dryness and heated at a temperature above 250°C. for two or three hours. By this heating the gypsum becomes dehydrated and almost insoluble, so all that is necessary is to extract with a small amount of water, filter and evaporate in a platinum dish for total alkali and titrate for chlorides. For dehydration a small round air-bath was made of Russia iron covered with asbestos and containing a rack for holding six smaller porcelain evaporating dishes. A number of experiments made with this method showed that it reduced the amount of soluble salts by about 60 percent, while chlorides remained the same and different amounts of water could be used without affecting the results.

Plats Nos. 19 and 20 were set apart for permanent experiments on the effect of rotation of crops on the composition of the soil. On No. 19 different crops will be grown in rotation and on No. 20 a single crop will be grown continuously for a number of years. The samples were taken June 19, 1896. No. 19 was virgin soil; No. 20 had been in crop one year.

Plats A, B and C were added to the farm June 24, 1899, for permanent irrigation experiments, and the samples were taken then. They were virgin soil and had never been irrigated. Plat A is to be irrigated with the minimum amount of water, Plat B will be given a medium quantity. while Plat C will be irrigated frequently and abundantly. The aim of the experiment is to determine the most advantageous duty of water, and as the amount of water used in irrigation has so important an effect on the accumulation of salts in the soil it was thought necessary to determine their distribution at the beginning of the experiment.

There is no general rule to be deduced from these analyses except that the amount of salts gradually increases as we go down. The individual variation in samples is surprisingly large. Sample No. 29, for example, has four times as much alkali as the average of its neighbors. All unusual results were duplicated. Plats A, B and C were supposed to be the same soil, but they contain in the first three feet, respectively, 4531, 1463 and 2886 pounds per acre of alkali salts.

Distribution of Alkali on the Experiment Farm.

Sample No	Plat No.	Distance from Surface	Total Alkali Per Cent.	Sodium Sulphate Per Cent.	Sodium Chloride Per Cent.	Total Alkali Pounds Per Acre	Sodium Sulphate Pounds Per Acre	Sodium Chloride Pounds Per Acre
11	19	0-3 inches	.053	.050	.003	530	500	30
12		3-6 inches	.064	.056	.008	640	560	80
13		6-9 inches	.089	.078	.011	890	780	110
14		9-12 inches	.067	.061	.006	670	610	60
		1st foot	.068	.061	007	2730	2450	280
15		12-15 inches	.080	.056	.024	800	560	240
16		15-18 inches	.068	.047	.021	680	470	210
17		18-21 inches	.058	.047	.011	580	470	110
18		21-24 inches	.042	.036	.006	420	360	60
		2nd foot	.062	.046	.018	2480	1860	620
19		24-27	.056	.043	.013	560	430	130
20		27-30	.054	.048	.006	540	480	60
21		30-33	.039	.036	.003	390	360	30
22		33-36	.048	.044	.004	480	440	40
		3rd foot	.049	.043	.007	1970	1710	260
		3 feet	.060	.050	.011	6980	6020	1160

Distribution of Alkali on the Experiment Farm.—(Continued).

Sample No.	Plat No.	Distance from Surface	Total Alkali Per Cent.	Sodium Sulphate Per Cent.	Sodium Chloride Per Cent.	Total Alkali Pounds Per Acre	Sodium Sulphate Pounds Per Acre	Sodium Chloride Pounds Per Acre
23	20	0-3 inches	.019	.005	.014	190	50	140
24		3-6 inches	.033	.027	.006	330	270	60
25		6-9 inches	.036	.032	.004	360	320	40
26		9-12 inches	.020	.016	.004	200	160	40
		1st foot	.027	.020	.007	1080	800	280
27		12-15 inches	.024	.020	.004	240	200	40
28		15-18 inches	.016	.014	.002	160	140	20
29		18-21 inches	.071	.070	.001	710	700	10
30		21-24 inches	.020	.017	.003	200	170	30
		2nd foot	.033	.030	.002	1310	1210	100
		2 feet	.030	.025	.004	2390	2010	380
120	A	0-4 inches	.033	.027	.006	440	360	80
121		4-8 inches	.027	.021	.006	360	280	80
122		8-12 inches	.033	.024	.009	440	320	120
		1st foot	.031	.024	.007	1240	960	280
123		12-15 inches	.031	.023	.008	413	306	106
124		16-20 inches	.029	.023	.006	386	306	80
125		20-24 inches	.036	.024	.012	480	320	160
		2nd foot	.032	.023	.008	1279	932	346
126		24-28 inches	.038	.019	.019	506	253	253
127		28-32 inches	.045	.020	.025	600	267	333
128		32-36 inches	.068	.036	.032	906	480	426
		3rd foot	.050	.025	.025	2012	1000	1012
		3 feet	.038	.024	.013	4531	2892	1638
129	B	0-4 inches	.018	.014	.002	240	214	26
130		4-8 inches	.011	.008	.003	146	106	40
131		8-12 inches	.008	.005	.003	106	66	40
		1st foot	.012	.009	.003	492	386	106
132		12-16	.011	.005	.006	146	66	80
133		16-20	.009	.003	.006	120	40	80
134		20-24	.007	.004	.003	93	53	40
		2nd foot	.009	.004	.005	359	159	200
135		24-28	.008	.005	.003	106	66	40
136		28-32	.009	.006	.003	120	80	40
137		32-36	.023	.020	.003	386	346	40
		3rd foot	.013	.010	.003	612	492	120
		3 feet	.011	.080	.004	1463	1037	426
138	C	0-4 inches	.012	.009	.003	160	120	40
139		4-8 inches	.011	.007	.004	146	96	50
140		8-12 inches	.018	.014	.004	240	190	50
		1st foot	.014	.010	.004	546	406	140
141		12-16 inches	.016	.013	.003	210	170	40
142		16-20 inches	.030	.026	.004	400	350	50
143		20-24 inches	.024	.020	.004	320	270	50
		2nd foot	.023	.020	.004	930	790	140
144		24-28 inches	.028	.024	.004	360	310	50
145		28-32 inches	.034	.024	.010	450	317	133
146		32-36 inches	.045	.032	.013	600	427	173
		3rd foot	.036	.027	.009	1410	1054	356
		3 feet	.024	.019	.006	2886	2240	646

WATER MEASUREMENTS

By B. C. BUFFUM.

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JULY, 1900.

LARAMIE, WYOMING.

Water Measurements.[*]

BY B. C. BUFFUM.

The water measurements made by the Station in 1891 and 1892 were reported in Bulletin No. 8. As this bulletin is out of print, the table of duties there reported is given below. Since 1892 measurements of the water used on the Station farm at Laramie have been made each year, and a series of measurements were made at Wheatland in 1893. The measurements at Laramie in 1893 were of no value, as all crops failed that season, and in 1894 the record was incomplete and not sufficiently accurate for publication. Since 1894, however, a large number of determinations of duty have been made. With the exception of some measurements in 1899 made in coöperation with Professor Elwood Mead of the Office of Experiment Stations, the duties so far determined are reported in the following tables:

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[*] All the measurements of water up to the close of the season of 1898 have been reported in Bulletin No. 81 of the Office of Experiment Stations of the U. S. Department of Agriculture, entitled "The Use of Water in Irrigation in Wyoming and its Relation to the Ownership and Distribution of the Natural Supply." The tables on duty given in this paper are the same as those used in that bulletin with the addition of report on the first year's measurement to show amount of water necessary to produce a maximum crop in 1899 and amount of water used in a sub-irrigation system at Laramie, along with the measurements for 1899 by the Station. The co-operative measurements for 1899 have been reported to Professor Mead of the Office of Experiment Stations.

TABLE I.—*Duty of water, Wyoming Experiment Station, 1891-92.*

Place.	Crops.	Yield per acre.	Rainfall for four months.*	Date irrigated.	Total amount of water used.	Average depth of irrigation water on land.	Duty of 1 cubic foot per second continuous flow.*
1891.			*Inches.*		*cu. ft.*	*Inches.*	*Acres.*
Laramie	Mixed	. . . .	6.16	. . . .	2,667,288.75	30.6	95.62
Wheatland	Oats	40 bushels	3.50	June 20 to July 12.	9,507,073.47	17.4	167.60
1892.							
Laramie	Sugar Beets Rutabagas	8.6 tons. 18 tons.	†6.99	June 16, 17 Aug. 16 Sept. 22	97,973.24	9.9	299.77
Do	Corn	Cut for fodder.	†6.99	July 20	10,848.39	4	735.29
Do.	Cane, durra	. . . .	†6.99	July 23	19,754.92	8.7	336.02
Do.	Peas, beans.	7 bushels.	†6.99	June 5	18,081.13	4.9	588.23
Do.	Mixed.	. . . .	†6.99	. . . .	1,180,511.41	13.5	216.06

*Four months of growing season—May, June, July and August. †5.13 inches fell in May and June.

TABLE II.—*Duty of Water on Alfalfa, 1891-1899.*

No.	Year.	Area.	Date Planted	No. of Irrigations	Water received by Irrigation per Acre.		Depth of Water Supplied by Irrigation and Rainfall in year	Depth of Water received by Irrigation and Rainfall in growing season*	Duty of 1 sec. ft. for season of 4 months.	Duty of 1 sec. ft. for season of 95 days.	Yield per Acre	Remarks.
					Quantity	Depth over Surface						
		acres.			*cu. ft.*	*ft.*	*ft.*	*ft.*	*acres*	*acres*	*lbs.*	
1	1893	1.	1891	6	113,184	2.60	3.13	2.71	93.8	72.6	15752	At Wheatland. Three crops.
2	1896	.52	1894	2	47.356	1.08	1.98	1.69	224.5	173.3	4664	Laramie. Two crops.
3	1898	1.	1898	4	129.388	2.97	3.61	3.35	82.0	63.4	2220	Laramie. First year.
4	1898	3.9	1894	5	113,101	2.60	3.24	2.98	94.0	72.6	8668	Laramie. Two crops
5	1899	3.87	1897-98	4	135,365	3.11	4.02	3.53	78.5	60.7	5319	Laramie. [nurse crop.
6	1899	.95	1897	3	84,663	2.14	3.05	2.56	125.5	97.0	5510	Laramie. Average yield with and without
7	1899	.50	1897	3	103,680	2.38	3.20	2.80	102.5	79.2	6206	Laramie. Sown with oats in '97, two crops.
8	1899	.70	1899	2	100,190	2.30	3.21	2.72	106.1	82.1	1187	Laramie. First year.
9	1899	.95	1897	1	42,689	0.98	1.89	1.40	249.0	192.3	3188	Laramie. One half of plat killed by alkali.
10	1899	.03	1895	3	78,219	1.82	2.73	2.24	135.9	104.9	7862	Laramie. Turkestan Alfalfa.
11	1899	.98	. . . .	3	103,900	2.38	3.29	2.80	102.3	79.0	. . .	Laramie. With Oats.
12	1899	.25	1899	3	104,226	2.39	3.30	2.81	102.0	78.8	. . .	Laramie. First year, with Oats.
13	1899	.96	. . . .	2	70,132	1.61	2.52	2.03	151.6	117.0	. . .	Laramie. With Oats.
14	1899	.46	1899	3	134,165	3.08	3.99	3.50	79.2	61.2	1766	Laramie. First year, with Timothy.
15	1899	5.4	1899	2	98,881	2.27	3.18	2.69	107.5	83.0	. . .	Laramie. First year, on sod with Oats.

*Growing season five months—May, June, July, August and September.

TABLE V—*Duty of water, mixed crops—Grains, peas, and flax, 1893-1898.*

CROP.	Place.	Year.	Water received by irrigation per acre.		Depth of water supplied by irrigation and rainfall.		Duty of 1 second-foot for season.	
			Quantity.	Depth over surface.	Growing season	Year	Four months.	Ninety-five days.
			Cubic Feet.	*Feet.*	*Feet.*	*Feet.*	*Acres.*	*Acres.*
Grains, root crops, hay and garden	Laramie	1895	50.266	1.15	1.82	2 08	211.4	163.3
Wheat, 18 varieties; oats, 3 varieties	do	1896	52,895	1.21	1.61	2.11	200.9	155.2
Barley, oats and wheat	do	1896	63,296	1.45	1.85	2.35	167.9	129.7
Garden (furrow irrigated)	do	1896	54.270	1.25	1.65	2.15	195.8	151.2
Grain (wheat, oats, barley, furrow irrigated)	do	1896	61,122	1.40	1.80	2.30	173.9	134.3
Wheat and oats (sod land)	do	1896	41,886	.96	1.36	1.86	253.7	196
Wheat (Blount No 16), oats (Lincoln)	do	1897	107.012	2.46	2 87	3 46	99.3	76.7
Oats, rye, barley, and flax	do	1897	69.345	1.59	2	2.59	153.4	118.4
Grain (varieties furrow irrigated)	do	1897	66,467	1.53	1 94	2.53	159.9	123 5
Oats (Surprise and grains furrow irrigated)	do	1898	67.477	1.55	1.93	2.19	157.5	121 6
Wheat (Blount No. 16), oats (Lincoln)	do	1898	75,853	1 74	2.12	2.38	140.1	108.2
Peas	do	1897	74,609	1.71	2.12	2.71	142.3	109.9
do	do	1897	136,408	3.13	3.54	4.13	78	60.2
do	do	1898	124,304	2.85	3.23	3 49	85.5	66
Barley (Highland Chief), wheat (Scotch of Scotch)	do	1898	75,159	1.73	2.11	2.37	141.4	109.1
Oats, rye, barley, and flax	do	1897	69,345	1.59	2	2.50	153 3	118.4
Flax, 2 varieties	Wheatland	1893	95,040	2.18	2.33	2.71	111.8	86.4

TABLE VI—*Duty of water, root crops, 1893-1898.*

CROP.	Place.	Year.	Water received by irrigation per acre.		Depth of water supplied land by irrigation and rainfall.		Duty of 1 second-foot for season.		Yield per acre.
			Quantity.	Depth over surface.	Growing season.	Year.	Four months	Ninety-five days.	
			Cubic feet.	*Feet.*	*Feet.*	*Feet.*	*Acres.*	*Acres.*	*Pounds.*
Potatoes	Laramie	1895	11,683	0.27	0.95	1.20	909.6	702.6	9,000
Do	do.	1896	13,866	.32	.72	1.22	766.5	592	. . . . .
Do	do.	1897	26,237	.60	1.01	1.60	405	312.8	. . . . .
Potatoes, 3 irrigations	do.	1898	49,825	1.14	1.54	1.78	213.3	164.7	8,675
Potatoes, 2 irrigations	do.	1898	12.925	.30	.68	1.94	822.2	635	5.131
Potatoes, 22 varieties	Wheatland	1893	61,776	1.42	1.57	1.95	172	132.9	7,344
Sugar beets and ruta-bagas	Laramie	1898	69.875	1.60	1.98	2.24	152.1	117.8	. . . . .
Sugar beets, 4 varieties	Wheatland	1893	107,128	2.46	2.61	2.99	99.2	76.6	12,912
Turnips and ruta-bagas	Laramie	1895	112,733	2.59	3.27	3.52	94.3	72.8	. . . . .

TABLE VII—*Duty of water for various crops, 1899, Laramie.*

No.	CROP.	Plat.	Area	No. of irrigations.	Water received by irrigation.		Depth of water received by irrigation and rainfall in growing season.	Duty of 1 second-foot for season of 4 months, 123 da.	Duty of 1 second-foot for 95 days.	Yield per acre.	Remarks.
					Quantity	Depth over surface					
			acres		*cubic ft.*	*ft.*	**ft.*	*acres*	*acres*	*pounds*	
1	Amethyst wheat . .		0.88	1	24,358	0.64	1.06	383.7	205.87	911	Cut green for hay.
2	Garden.		1.5		148,603	2.27	2.69	107.3	82.85	. . .	Root crops, pease, lettuce, cabbage, etc.
3	Artichokes	4	0.27		7,685	.65	1.07	297.5	289.1	5300	Estimated from yield of one row.
4	Brome grass	9	0.41	3	46,190	2.60	3.02	93.9	72.5	593	Second year from sowing the seed.
5	Sand vetch	9	0.57	1	10,954	.44	.86	549.5	424.3	1174	
6	Grasses	16	0.95	3	75,430	1.82	2.24	106.3	103.4	. . .	Varieties in small plats.
7	Potatoes		0.99	1	46,030	1.07	1.49	228.5	176.5	3062	Yield is of marketable tubers.
8	Potatoes	3	0.68	1	18,065	.61	1.03	401.4	310.	3445	Yield is of marketable tubers.
9	Potatoes	8	0.30	1	10,080	.77	1.19	177.2	136.8	3616	Yield is of marketable tubers.
10	Grain	21	0.98	2	61,735	1.45	1.87	172.3	113.9	864	Yield given is of barley; yield of wheat is 939 lbs., and of rye 449 lbs.
11	Bonanza oats. . . .	19	0.96	2	66,868	1.59	2.01	153.3	118.4	1436	
12	Oats and wheat. . .	8	0.65	2	40,896	1.43	1.85	170.	131.3	1738	Yield given is of oats; yield of wheat is 1 444 lbs.
13	Mixed crops, grain, pease, millet . . .		2.39	2	164,929	1.57	1 99	155.2	119.87	. . .	
14	Wheat and oats. . .	20	0.97	2	58,045	1.38	1.80	176.7	136.5	836	Yield is of oats; wheat yielded 516 lbs.
15	Pease	22	0.98	2	69,490	1.63	2.05	149.8	115.7	5070	Cut green for hay.
16	Wheat	3	0.25	2	14,220	1.31	1.73	186.8	144.3	1037	
17	Dwarf Essex Rape .	1	0.11	1	11.773	2.39	2.81	101.9	78.8	31920	Yield given is the weight of green crop.
18	Oats		0.26	1	8,098	.75	1.17	324.8	250.8	802	Small plat on alkali ground.
19	Potatoes		0.34	2	12,726	.85	1.22	286.0	220.9	. . .	

*Rainfall for growing season of May, June, July, August and September is 0.42 feet.

SUB-IRRIGATION.

Two systems of sub-irrigation have been under observation for a number of years. One of these consists of an iron pipe two inches in diameter and 900 feet long, used on the campus for irrigating trees.* This pipe has given very satisfactory results, but it has not been practicable to measure the amount of water used in it. The other system consists of one-half acre on the Experiment Farm which is underlaid with porous tile. Lines of four-inch tile are placed eighteen inches deep and at distances of twenty feet apart. These lines of pipe join six-inch mains extending around the plat, which serve as feed and drain pipes. The system was established in the spring of 1895 and that season the land was planted to varieties of small fruits. These failed to grow and since 1895 the plat has produced other crops in rotation—turnips, oats, potatoes, and wheat. Previous to last season the measuring of water used in sub-irrigating this plat was neglected. Last season a series of careful measurements were made to show how much water was used. It should be stated that the soil is a sandy loam,mixed with gypsum, which gives it a sticky, clay-like consistency, with gypsum and lime subsoil at about the depth the tile is laid. Water does not pass through this soil readily and the pipes are too far apart, so the crop midway between the lines of pipe does not receive enough water. This is very apparent when grain is grown on the plat, as it makes tall, thrifty growth over the pipes and short growth between. giving the plant a wave-like aspect, like the surface of a washboard or the smooth swells of an unruffled sea. Last season the plat was planted to wheat, which was irrigated by letting water run into the pipes at night, keeping careful records of the time and depth with a water register. A very small head was used, the water flowing over an eighteen-inch weir with an average depth of a little more than one-half inch. The measurement, as reported below, is approximately correct. The area of the plat was 0.465 acre.

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*For description see Wyo. Sta. Bul. No. 8, p. 23.

TABLE VIII—*Duty of Water.—Wheat Sub-irrigated, 1899.*

Water received by sub-irrigation.		Depth by Irrigation and Rainfall, growing season.	Duty of 1 second foot for season.		Yield per acre.	
Quantity.	Depth on surface.		Four months	Ninety-five days.	Straw and Grain	Yield, Grain.
cubic ft.	*ft.*	*ft.*	*acres.*	*acres.*	*lbs.*	*lbs.*
62546	3.091	3.51	79.1	61.2	3873	962*

*Blackbirds took much of the grain before it was threshed.

Irrigation began June 29 and ended August 2nd. We have long known that the value of land in Wyoming is not yet sufficiently great to merit the first expense of establishing such systems of sub-irrigation. Our results with this plat do not indicate that extraordinary crops are produced by this method of applying water, or that it is economical from the standpoint of the amount of water required to produce a crop. More water was used on the sub-irrigated land last season than on any other plat on the farm except one small field of alfalfa.

AMOUNT OF WATER NECESSARY TO PRODUCE A MAXIMUM CROP.

All our determinations of duty have been compared with crop production, but no experiments were carried out to determine the amount of water most favorable to crops, or the amount necessary to produce a maximum yield until last year. About eleven acres of the new land which was planted to oats was divided into three plats, marked A, B, and C. The plan was to give plat C what would ordinarily be called an excessive amount of water, give B medium irrigation, and supply A with as little water as would mature the crop. Table IX gives the data computed from last season's notes.

TABLE IX—*Amount of Water to Produce Maximum Crop.—Oats, 1899.*

Plat.	Area in acres.	Date planted.	No. of irrigation	Date irrigated.	Water received by irrigation.			Depth of water supplied land by irrigation and rainfall, growing season.	Date harvested.	Height of grain when ripe.	Average length of heads.	Yield per acre.	
					Quantity.	Depth over surface	Total depth					Straw and Grain.	Grain.
					cubic ft.	*ft.*	*ft.*	*ft.*		*ft.*	*ft*		
A	2.78	April 24-26	1	June 30 July 1	78376	0.65							
			2	July 25-26	23778	0.19	0.845	1.265	*Sept. 4	2.1	0.45	1071	491
B	4.94	do	1	June 27-30	201893	0.94							
			2	July 17-18	95586	0.44	1.38	1.80	Sept. 3-4	2.3	0.45	1229	446
C	4.41	do	1	June 24-26	160828	0.84							
			2	July 12-17	118549	0.62							
			3	July 22	72195	0.35							
			4	Aug. 2	59496	0.31	2.14	2.56	Sept. 3	2.5	0.55	1489	567

*Plat A ripened a little later than the other plats, though there was but little difference in time of ripening.

The results do not indicate that even the largest amount of water applied was sufficient to produce a maximum crop. Sod land requires more water than is necessary on older cultivated soil, and the largest amount or water applied was not excessive. The time of applying water is of great importance. Irrigating at the wrong time may account for the decrease in yield of grain in Plat B, while the amount of straw was increased by the additional water it received.

Samples of soil were taken from each plat twice each week during the summer for determinations of the amount of moisture in the soil. A part of the determinations were made by Mr. Danielson and a part by Mr. Moudy in the Chemical Department. The soil samples were taken by driving iron tubes into the ground a distance of one foot. They were corked up with rubber corks at each end until they could be dried. The samples obtained in this way were not uniform. Sometimes the tube would drive into the soil, filling nearly its whole length, and at other times the soil would apparently drive down ahead of the lower end, so that not more than one or two inches of soil would be obtained. This throws doubt on the uniformity of the samples taken and makes the moisture determinations of little or no scientific value. However, there were fifteen determinations from each plat, and the averages show small differences in the percent of moisture from each. With this explanation, the moisture determinations are published in Table X. Plat A, which had the least irrigation, apparently had the largest average moisture content, though the variation is small and may be accounted for by the way the samples were taken.

TABLE X—*Soil Moisture in Plats A, B, and C, 1899.*

Plat.	July 11.	July 14.	July 17.	July 20.	July 24.	July 28.	July 31.	August 3.	August 6.	August 12.	August 15.	August 18.	August 22.	August 25.	August 28.	Average.
A. .	3.38	6.89	8.78	9.56	8.41	16.48	15.30	13.05	16.66	12.99	9.55	11.17	7.96	7.27	8.19	10.38
B . .	3.85	8.81	17.49	11.59	8.59	8.48	9.13	6.32	12.00	5.11	4.29	6.40	4.44	5.35	3.34	7.68
C . .	3.93	9.88	16.06	12.00	11.35	11.96	12.00	13.19	11.58	9.46	5.38	6.55	3.62	3.85	3.88	8.98

In 1898 an experiment to show the effect of different amounts of water on potatoes was carried out.*

"A part of the potato field was given the first irrigation July 7, while a part was left until July 28 for the first watering, at which time the potatoes irrigated on July 7 were given their second irrigation, and all were irrigated again on August 4. The potatoes were planted in rows running across two plats, one of which was plowed in the ordinary way. The other plat was treated the same, but had been subsoiled in the spring of 1896 to a depth of 16 or 18 inches. The potatoes irrigated twice received 3.6 inches of water, while those irrigated three times received 13.8 inches. The yields of marketable potatoes per acre are given in the following table:

TABLE XI— *Yield of Potatoes with Two and Three Irrigations.*

Irrigations.	Land plowed	Land plowed and subsoiled.	Average yield.
	Pounds.	*Pounds.*	*Pounds.*
Irrigated twice	4,972	5,290	5,131
Irrigated three times	8,759	8,591	8,675
Increase.	3,787	3,301	3,544

"This table shows an increased yield due to the additional irrigation of over 76 percent on land treated in the usual way, and of nearly 62.4 percent on subsoiled land, the average increase being over 69 percent."

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*Bulletin No. 81, Office of Experiment Stations, U. S. Department of Agriculture.

Some studies made by the writer on the amount of water on amount of crop, which were published in Bulletin No. 81 of the Office of Experiment Stations, "The Use of Water in Irrigation in Wyoming," were summarized as follows:

* * * There is a limit to the volume of water which can be used to advantage, beyond which it is an injury to both land and crop. With alfalfa the largest yield was obtained with the least water per pound produced, and the same is true in several cases with the grains and potatoes. However, * * * the results indicate that in general the greatest depth of water applied to the crop by irrigation nearly corresponds to the maximum yield, except in the case of grains on sod land, or potatoes, which received little irrigation.

"It will thus be seen that we are unacquainted as yet with the amount of water necessary to produce the best results under any known conditions. With too little water. failure of the crop is certain, and too much water is often injurious. So far, we have been able to obtain only a general idea of the amount of water necessary to carry on successful agricultural operations and produce crops which give larger average yields than those raised under rainfall. Undoubtedly, applying water to the plant when it needs water and not forcing it to exist in the presence of water in excess of that required is the only scientific way of producing crops."

GERMINATION OF WHEAT AND OATS TREATED FOR SMUT.

PUBLISHED AS PART OF THE TENTH ANNUAL REPORT OF THE
WYOMING AGRICULTURAL EXPERIMENT
STATION.

The loose smut of oats and the stinking smut of wheat are very troublesome on the Laramie Plains. Unless the seed planted be absolutely free from the smut spores it is impossible to raise clean grain, and if untreated seed is planted, even though it appears to contain very little smut, the loss to the resulting crop is great. In one instance, actual count of kernels after threshing gave 80 smut kernels to 42 sound ones, or over 190 percent smut, and many of the diseased kernels were broken to pieces in the threshing. Several different methods of treating grain for smut were resorted to the present season and after treatment as nearly average samples of the grain as could be selected were placed in the germinating chamber to determine the effect of the treatment on vitality of the seed. Several samples of untreated seed were germinated as checks. The observations were made April 16 to 27, 1900. The methods of treatment were as follows:

COPPER SULPHATE OR BLUE STONE TREATMENT:—A solution was made by dissolving one pound of commercial copper sulphate in twenty-four gallons of water. Amethyst wheat and Lamona wheat were soaked in this solution for ten and one-half hours. Scotch of Scotch wheat was soaked for thirteen hours. Upon removing the wheat from the sulphate solution it was immersed for five minutes in a solution made by slacking one pound of good lime and then diluting to ten gallons with water.

POTASSIUM SULPHIDE TREATMENT.—A two per-cent solution was made by dissolving eight pounds of potassium sulphide in fifty gallons of water. Surprise and Lincoln oats were soaked in this solution for two hours and then spread out to dry.

THE JENSEN HOT WATER TREATMENT:—Two barrels of water were heated by passing steam into them. A reliable thermometer was used to test the temperature. The water in barrel No. 1 was heated to about 130°F. The grain in sacks was placed in this water, which would lower the temperature ten or fifteen degrees when immersed. The water in barrel No. 2 was heated to from 130 to 135°F. The grain was lifted from barrel No. 1 to barrel No. 2 and left in the water heated to 130 or 135°F. for ten minutes. If the temperature decreased to less than 130°, the grain was lifted out and steam passed in to increase the heat to the proper degree, when the grain was replaced until the actual time it was immersed amounted to a total of ten minutes. In some instances when the water was at a lower temperature than 130°F., the grain was left in longer than the ten minutes specified for the proper temperature, i. e., the time the grain was in the water was not counted unless the temperature was at or above a minimum of 130°F. Scotch of Scotch wheat, Surprise oats and Lincoln oats were treated in this manner. Great care was taken not to have the water too hot or leave the grain in too long, but the result on the germination of the seed shows that too much heat was applied. All the grain treated, except the Lamona wheat, was raised at Laramie in 1899. It is possible that grain raised at this altitude, on account of its rapidity of growth and the short season, does not produce seed coats which are so thick as that of grain raised where the season is long, and that the thin seed coats account for the destruction of germinating power by water at a temperature supposed to be safe in other places, or by the salt solutions commonly used elsewhere. The following table gives the results of the germinating test of the treated grains compared with check samples not treated:

Germination of Wheat and Oats Treated for Smut.

No.	Grain.	Treatment.	Percent germinated each day from time of planting.								Total per cent germinated.	Seed from.
			1	2	3	4	5	7	9	11		
1	Wheat, Lamona. . . .	None	16	97	99	100	..	..	..	..	100	U. S. Dept.
2	" "	Copper Sulphate. .	7	49	77	89	91	93	97	..	97	U. S. Dept.
3	" Amethyst. . . .	. . . . do	1	13	46	64	71	76	80	81	81	Laramie.
4	" Scotch of Scotch	None	..	74	88	96	..	97	..	..	97	do
5	" "	Copper Sulphate. .	13	68	74	79	82	84	85	..	85	do
6	" "	Hot Water.	..	..	..	1	3	6	..	..	6	do
7	" Chili	Corrosive Sublimate	..	62	78	86	88	92	..	93	93	do
8	Oats, Surprise	None.	..	..	27	51	68	81	82	..	82	do
9	" "	Potassium Sulphide.	..	..	30	46	..	52	54	57	57	do
10	" "	Hot Water.	..	..	9	13	16	20	23	28	28	do
11	" Lincoln	None.	..	..	34	81	94	97	98	..	98	do
12	" "	Potassium Sulphide	..	..	30	46	53	55	56	57	57	do
13	" "	Hot Water.	..	..	6	14	23	26	..	28	28	do

FORAGE PLANTS

By B. C. BUFFUM and W. H. FAIRFIELD.

PUBLISHED AS PART OF THE TENTH ANNUAL REPORT OF THE
WYOMING EXPERIMENT STATION.

JULY, 1900.

LARAMIE, WYOMING.

Forage Plants.

BY B. C. BUFFUM AND W. H. FAIRFIELD.

It is the object of this paper to report briefly and more or less technically the investigations by the Experiment Station with cultivated and native forage plants for the Laramie Plains. The Station early took up work with forage plants and Bulletin No. 16 was the first report on them. This bulletin gave accounts principally of the native forage plants which had been collected up to that time. Brief reports have been made from time to time by this and other departments, more especially with forage plants for alkali soils.*

No subject which is being investigated promises results of so great value to the farmers of the State. Where live stock is the basis of agricultural practice, as it is and must be in Wyoming, the importance of raising abundant and cheap stock food can hardly be overestimated. The natural ranges have greatly deteriorated through over-stocking, which has prevented the best grasses from re-seeding themselves for so long a time that they have run out. Not only is the improvement of the native range important, but greater hay production from our native and cultivated meadows is a matter of prime importance. No doubt there are many grasses and forage plants which can be introduced and cultivated that will greatly increase the yield of hay obtained. This matter is of such vital interest that our farmers and ranchmen are ever ready to spend their money for greatly advertised grasses or forage plants, and go to much trouble and expense giving them trial on their hay lands. Many bought sachaline, which proved absolutely valueless in every part of the state. Many more are buying Australian salt bush, which is a tropical plant and will not succeed in our climate. Ranchmen everywhere are now buying seed of the Awnless Brome grass, which our experiments have shown is poorly adapted to our ***high*** altitudes. It seems that a ton of it will cost more than it will ever be worth, as it makes slow growth and produces very small yields at Laramie. However, it is a valuable grass in some localities, especially where the rainfall reaches 17 to 20 inches per annum.

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*See Wyo. Sta. Bul. No. 42, by Aven Nelson, Botanist of the Station.

We have tried many varieties of grasses and many kinds of other forage plants. In 1895 we began co-operation with the Division of Agrostology of the United States Department of Agriculture, from which source we obtained many varieties of seed which are not obtainable as yet except in very small amounts as collected in the native home of each plant. These have been grown with the hope that some among them might prove worthy of extended planting and spreading of the seed among our farmers. Results of value have been obtained. Some of the kinds tried have already been proven worthless, others have not yet been sufficiently investigated to enable us to form an opinion of their value, and still others have given most promising results. We believe the following brief report of these trials will be of interest and value.

At the end of this report we have given three lists of forage plants, the first one being a list of those which have shown themselves worthy of further trial, the second one being a list of those which have not yet furnished sufficient data from which to determine their usefulness, or uselessness, and the third one being a list of those which have proven themselves useless under the conditions of climate at our high altitude. The second list, no doubt, contains many plants which are valueless at this altitude, but unless our results have been such as to fully prove them so, we have given them the benefit of the doubt.

ALFALFA *(Medicago sativa.)*

Results obtained by the Station in cropping alfalfa are reported in Bulletin No. 43, and need not be repeated here. Its value as a fertilizer was reported in Bulletin 44. No other forage plant which has been tried approaches alfalfa in general value. It ranks first in Wyoming. It is productive and adapts itself to our conditions of soil and climate. Alfalfa must be irrigated and cannot be grown on low wet land. At altitudes over 6,000 feet it should be given special preparation of the land and be planted with a press drill.

ALSYKE *(Trifolium hybridum.)*

A plat planted in 1896 made a poor stand. The plants grew well in the summer of 1897 but winter killed the following winter. Plants have spread to different parts of the farm and grow well along the ditches, or where covered with snow drifts in the winter. It may have some value to improve wet meadows, especially in sheltered places.

RED CLOVER *(Trifolium pratense.)*

A plat planted with press drill May 1st, 1894, made poor stand. Harvested August 9, 1895, and yielded 1,426 pounds per acre. Another plat planted May 23, 1896, made a scattering stand. It was cut to clean off weeds in 1897. In 1898 the plat yielded 2,628 pounds per acre. In 1899 it yielded 1,080 pounds per acre and 1,800 pounds per acre in 1900. Red clover is apt to winter kill at this altitude and cannot be expected to produce a crop the first season from seed.

Mammoth red clover was planted in 1896. In 1897 it was growing, but a poor stand was secured, and practically all was winter killed in following winter.

CRIMSON CLOVER *(Trifolium incarnatum.)*

Has been tried at Laramie but failed.

WHITE CLOVER *(Trifolium repens.)*

Is used in lawns. Grows well and spreads rapidly where kept wet. Is apt to winter kill.

EGYPTIAN CLOVER *(Trifolium Alexandrinum.)*

Planted May 22, 1896. Good stand. Blossomed August 5. Grew six to eight inches high. Was not cut.

BOKHARA CLOVER *(Mililotus alba.)*

Planted on May 21, 1896, on alkali ground. Produced only a medium stand. Cut in 1897 but no record of yield was kept.

Planted May 12, 1897, on alkali land with press drill. August 1, 1898, plants in full bloom. Highest plants, 6½ feet. Yield cured hay, 9,226 pounds per acre. In 1891 some seed was planted on high land which could not be irrigated. It grew 9 inches high the first season and ripened seed the second year, re-seeding for several years. This clover is a great drouth and alkali resisting plant. It has a strong odor and is unpalatable to stock. In the presence of superior forage it is hardly worth while to attempt to educate stock to eat it. Its only value in our state is as a honey plant (for which purpose it is superior to almost any other), and as a plant to grow on strong alkali ground for green manure. See Wyo. Sta. Bul. No. 16, p. 236.

BURR OR CALIFORNIA CLOVER *(Medicago maculata.)*

Planted in 1895. Grew well and re-seeded every year for four years. This is a small annual recumbent clover which would only be of value for pasturage, where the seed could be harrowed in each year.

FLAT PEA *(Lathyrus sylvester wagneri.)*

The seed was planted and the roots were also set out in the spring of 1895. It makes a luxuriant growth, resists drouth well and does not winter kill. We cut it but once during the season. Its serious and, in Wyoming, fatal drawback, like the sweet clover, is lack of palatability. We have not been able to induce stock to touch it, either green or cured for hay. It requires three or four years for it to become well enough established to produce heavy yields at Laramie.

ENGLISH OR DWARF ESSEX RAPE *(Brassica napus.)*

In 1894 rape planted on alkali soil yielded 14.59 tons green forage per acre. In 1899 it yielded 15.95 tons green forage per acre. It is relished by stock and will be eaten through the winter as long as any of it is left standing. After being frosted, if eaten by milch cows it is apt to give an unpleasant flavor to the milk and butter. It is necessary to plant rape each year, but it promises to be of great value, especially for alkali land.

BROME GRASS *(Bromis inermus.)*

The first plat was planted in the spring of 1896. Since then two or three more plats have been planted. We have given it a very thorough trial and find that it is easy to start, resists drouth and our severe winters, but will produce scarcely enough hay to pay for cutting. One plat of nearly one-half acre yielded at the rate of 593 pounds cured hay per acre in 1899, and this is representative of what it has done during the four years we have tried it on the Station Farm at Laramie. It might be well to state, however, that at lower altitudes in the state, particularly in the vicinity of Sundance, it had proved itself to be of much value as a hay crop.

SANFOIN OR ESPARSETTE *(Onobrychis sativa.)*

This was planted with a press drill on native prairie in 1892. It was irrigated the first season. It made some growth, resisted drouth well, and did not winter kill. It may prove of value to improve the range, but no experiments in this particular line have yet been carried out. In 1896 a plat was planted and made a scattering stand. It made a good growth in 1897 but the yield was not taken. In 1898 it yielded at the rate of 4,666 pounds cured hay per acre, and in 1899, 2,736 pounds. On the whole it seems to be a very promising forage plant for this region, but does not yield so much hay as does alfalfa.

TALL MEADOW OAT GRASS *(Arrhenatherum avenaceum.)*

Planted in 1896 but did not come up till 1897 and only made a scattering stand; consequently the yield obtained was light, it being only 1,584 pounds cured hay per acre in 1899. Owing to the fact that it attains a height of between three and four feet comparatively early in the season and does not require an excessive amount of water, it may prove of value to use as a mixture with alfalfa.

TIMOTHY *(Phleum pratense.)*

This has been given careful trial since 1891 on the Station Farm. We find that on high open places exposed to the drying winds of winter which prevent snow remaining long on the ground, timothy does not do well. It does not seem to grow vigorously and is apt to winter kill. One plat yielded at the rate of 2,444 pounds of cured hay per acre in 1898 and 1,080 pounds in 1899. It can be recommended for meadows which are kept comparatively wet.

MILLET *(Panicum milaceum.)*

No. 2795 from the United States Department of Agriculture yielded 3,569 pounds per acre of cured hay in 1899. The seed was sown very thickkly. The plants were frosted August 24 before they matured. A number of kinds of millet have received trials but the season at this altitude is not long enough for them.

HAIRY OR SAND VETCH *(Vicia villosa.)*

1898—Planted May 11 and 13 with oats. One plat yielded 4,666 pounds per acre and the other plat gave a yield of 4,659 pounds per acre of cured hay. This yield was oats and vetch. A second cutting of the vetch was made in September, giving a yield of 888 pounds per acre.

1899—Yielded 1174 pounds per acre on August 7. About one-half the plants were killed during the winter.

The Station received on March 1, 1897, seeds of one hundred thirty-five different forage plants from the Division of Agrostology of the United States Department of Agriculture. These consisted principally of native grasses collected in and adjacent to the Rocky Mountains. As only small amounts of seed were received only small plats could be planted. A portion of Acre Plat 16 on the Farm was laid aside for the work and carefully prepared. Plats three by three feet, or containing nine square feet, were laid out with paths two feet wide on two sides and one and one-half feet wide on the other two sides of each plat.

On July 15, 16 and 17 the seeds were planted by hand and carefully raked in. Begining on July 17, the plats were watered with a sprinkling pot night and morning, except when it rained, for one or two weeks, or until the majority of the plants were up. On August 18, banks were laid up on the paths running north and south so that bed irrigation could be practiced with each tier of plats. The plats were then irrigated on the following dates: August 18, 24 and September 4. In 1898 the plats received thorough irrigations on June 16, July 2, July 25, September 2 and September 16. In 1899 the plats were irrigated June 10, August 4 and 5 and September 28.

The following is a list of the forage plants sown, together with notes on their growth and condition in 1898 and 1899, respectively. In reporting the height and length of heads the meter is the unit of measure used. The yield per acre is computed in some instances, which will be, of course, only approximately correct, on account of the extremely small area of the plats, nine square feet in each.

Agropyron acutum (Europe.)

1898—

Aug. 3, fair stand; fully headed; height, 1.08 m.; cut, weight, cured, 1 lb., 8.5 oz.

1899—

June 9—Good stand.

July 14—Beginning to head.

Aug. 8—Height, 1.05 m.; fair stand; just starting to change color at the tips of the heads; cut; weight, green, 2.5 lbs; weight, cured, 1 lb. 3 oz.; 2.8 tons cured hay per acre.

Agropyron caninum R. & S.

1898—

Aug. 3—Good stand; fully headed; height, 1 m.; cut; weight, cured, 2 lbs., 3.8 oz.

1899—

June 9—Good stand.

July 20—Heading.

Aug. 21—Beginning to ripen; fair stand but only headed around the edges; height at edges, 0.46 m.; cut; weight, green, 1 lb, 15 oz.; 4.6 tons green fodder per acre; 2.3 tons cured hay per acre.

Agropyron divergens.

1898—

Fair stand; fully headed; height, 0.8 m.; cut; weight, cured, 10 oz.

1899—

July 7—Headed; varies in height.

July 25—Height, 0.55 m.; length of heads, 0.15 m.; good stand; yellowing; cut; weight, green, 1 lb.; weight, cured, 8.5 oz.; 1 1-3 tons cured hay per acre.

Agropyron pseudorepens.

1898—

The grass growing is evidently not the species named.

Agropyron repens, Beam.

1898—

Aug. 3—Headed; good stand; height, 0.75 m.; cut; weight, cured, 3 lbs., 6 oz.

1899—

Aug. 8—Heading; height very uneven.

Sept. 26—Ripened by frost; headed on edges of plat, not in center; height on edges, 1.2 m.; cut; weight, green, 2 lbs., 12 oz.; weight, cured, 1 lb., 9 oz.; 3.8 tons cured hay per acre.

Agropyron richardsonii, School.

1898—

Aug. 3—Good stand; headed; cut; weight, cured, 2 lbs., 5 oz.

1899—

July 20—Headed around edges of plat.

Aug. 21—Heads changing color; poor to fair stand; height, 0.6 m.; cut; weight, green, 2 lbs., 2 oz.; weight, cured, 1 lb., 3.5 oz.; 2.9 tons cured hay per acre.

Agropyron spicatum, S. & S.

1898—

Aug. 3—Good stand; headed; height, 0.6 m.; cut; weight, cured, 1 lb.

1899—

Sept. 26—Not headed; fair stand; height, 0.18 m.; not cut.

Agropyron tenerum, Vasey.

1898—

Aug. 3—Very good stand; lower leaves much thicker than on the other agropyrons; headed; height, 1 m.; cut; weight, green, 3 lbs.

1899—

July 24—Heading around edges of plat.

Aug. 21—Heads changing color some; good stand but few heads in center of plat; height, 0.7 m.: cut; weight, green, 1 lb., 7 oz.; weight, cured, 14 oz.: 2.1 tons per acre of cured hay.

Alopecurus occidentalis.

1898—

Aug. 3—Only two or three small plants; ripe; height. 0.53 m.; cut; weight, cured, 1.5 oz.

1899—

June 9—Headed.

July 7—Stand thin; only a few stems; seeds starting to ripen; height, 0.43 m.; length of heads, 0.015 m.; weight, cured, 1 oz.

Andropogon cinhatus.

Dead.

Andropogon nutans avenacens, Hack.

Dead.

Andropogon provincialis, L. *(A. furcatus,* Muhl.)

Dead.

Andropogon scoparius.

Dead.

Arrhenatherum elatius, M. & K.

1898—

Aug. 3—Badly mixed; two distinct varieties; cut together; weight, cured, 2 lbs.

1899—

July 7—Headed; two species mixed.

July 25—Good stand; height, 0.95 m.; cut; weight, green, 1 lb., 12.5 oz.; cured, 12.5 oz.; 1.9 tons cured hay per acre.

Arundinaria macrosperma, Michx.

Dead.

Astragalus carolinianus, L.

Never came up.

Astragalus crassicarpus, Nut.

Never came up.

Atriplex canescens, James.

Dead.

Atriplex halimoides.

Dead.

Atriplex leptocarpa.

Dead.

Atriplex nummularia.

Dead.

Atriplex semibaccata.

Dead.

Atriplex truncata.

Dead.

Australia Old Man Salt Bush.

Never came up.

Beckmannia erucaeformis, Host.

1898—

Aug. 3—Headed; poor stand; starting to ripen; height, 0.53 m.; cut; weight, cured, 5.3 oz.

1899—

Dead.

Bigelovia graveoleus albicaulis.
Never came up.

Bouteloua eriopoda, Torr.
Dead.

Bouteloua juncifolia, (H. B. K.) Lag.
Dead.

Bouteloua microstachya.
Dead.

Bouteloua oligostachya, Torr.
1898—
Aug. 3—Fairly good stand; not headed; height, 0.1 m.
1899—
July 14—Fair stand; short tufted; height, 0.06 m.
Sept. 26—Has not grown since July 14 in center of plat; an occasional head near edges of plat; height here about 0.4 m.

Bouteloua racemosa, Lag.
Dead.

Bouteloua rothrockii, Vasey.
Dead.

Bromus adoensis.
Dead.

Bromus carinatus.
Dead.

Bromus ciliatus, L.
1898—
Aug. 3—Good stand; headed; height, 0.8 m.; weight, cured, 1 lb., 10.5 oz.
1899—
July 7—Edges heading; center of plat not heading.
Aug. 8—Height, 0.7 m.; changing color; cut; weight, green, 2 lbs; cured, 15 oz.

Bromus inermus, Leys.

1898—

Aug. 3—Very good stand; partially headed; a thick mat of grass; cut; height, 0.9 m.; weight, cured, 1 lb., 14.5 oz.

1899—

July 7—Heading.

Aug. 8—Heads not abundant; changing color; height, 0.8 m.; cut; weight, green, 2.5 lbs.; weight, cured, 1 lb., 1.5 oz.; 2.6 tons cured hay per acre.

Bromus purgans.

1898—

Aug. 3—Headed; good stand; height, 0.92 m.; cut; weight, cured, 1 lb., 4.7 oz.

1899—

July 7—Headed on edges of plat.

July 20—Well headed.

Aug. 8—Changed color some; height, 0.75 m.; cut; weight, green, 1 lb., 12 oz.; weight, cured, 13 oz.; 2.0 tons cured hay per acre.

Bromus tectorum, L.

1898—

Aug. 3—Very fine stand; fully headed and ripe; height, 0.6 m.; cut; weight, cured, 4 lbs., 8.5 oz.

1899—

July 1—Headed; spreading out larger than the original plant.

July 25—Height, 0.55 m.; cut; weight, green, 5 lbs.; weight, cured, 2 lbs., 6.5 oz.; 5.8 tons cured hay per acre.

Bromus unioloides.

Dead.

Bulbilis dactyloides, Raf.

Dead.

Calamagrostis canadensis.
Never came up.

Calamagrostis confinis.
Never came up.

Calamagrostis dubia.
Dead.

Calamagrostis purpurascens.
1898—
Aug. 3—A few small plants not yet headed; height about .13 m.
1899—
July 7—Headed; height, 0.35 m.
Aug. 8—Species mixed; plat not cut.

Calamovilfa longifolia.
1898—
Sept. 26—Poor stand.
1899—
Dead.

Carex straminea.
Dead.

Chaetochloa glauca.
Dead.

Chloris elegans.
Never came up.

Chloris verticillata.
Dead.

Dalea alopecuroides.
Dead.

Dasylirion texanum, Sotol.
Never came up.

Deschampsia caespitosa, Beauv.

1898—

Aug. 3—A few plants not yet headed; about 0.5 m. high.

1899—

July 7—Headed.

Aug. 8—It is doubtful if this is the species named; ripe; height, 0.45 m.; was not cut.

Desmodium tortuosum.

Dead.

Eatonia obtusata.

1898—

Aug. 3—Two or three plants headed; height, 0.6 to 0.7 m.; cut; weight, cured, 1.3 oz.

1899—

July 7—Heading.

Aug. 8—Nearly ripe; poor stand; height, 0.62 m.; cut; weight, cured, 3 oz.

Eleusine australis, Scribn.

Never came up.

Elymus canadensis, L.

1898—

Aug. 3—Very good stand; headed; height, 0.9 m.; cut; weight, cured, 5 lbs., 9 oz.

1899—

July 14—Good stand.

Aug. 8—Heading.

Sept. 16—Seed ripe; probably hastened by frost; is about the same height in center of plat as on edges, which is not the case with most of the species in experiment; height, 1.1 m.; cut; weight, green, 3 lbs., 10 oz.; weight, cured, 2 lbs., 9 oz.; 6.0 tons cured hay per acre.

Elymus canadensis glaucifolius.

1898—

Aug. 3—Fair stand.

Aug. 29—Headed; height, 1 m.; length of heads, 0.14 m.: cut; weight, cured, 1 lb., 8 oz.

1899—

Sept. 26—Headed: still green; height, 1 m.; cut: weight, green, 2 lbs., 1 oz.; weight, cured, 1 lb., 5 oz.: 3.1 tons cured hay per acre.

Elymus giganteous (Europe).

1898—

Aug. 3—Very good stand: headed; height, 1 m. to 1.2 m.: cut: weight, cured, 3 lbs., 13.7 oz.

1899—

July 14—Good stand; apparently a promising plant.

Aug. 8—Heading.

Sept. 26—Heads ripened by frost: height, 1 m.: cut: weight, green, 4 lbs., 11 oz.; weight, cured, 2 lbs., 13.5 oz.

Elymus glaucus, Buckl.

Never came up.

Elymus virginicus, L.

1898—

Aug. 3—Very good stand; just starting to head.

Aug. 15—Height, 0.83 m.: cut; weight, cured, 2 lbs., 11.5 oz.

1899—

July 14—Good stand; abundant foliage.

Sept. 26—Headed; still green; height, 0.7 m.; cut; weight, green, 3 lb., 13.5 oz.; weight, cured, 8.5 oz.; 6.1 tons cured hay per acre.

Eurotia lanata, L.

Dead.

Eragrostis abyssinica, Teff.
Dead.

Eragrostis purshii.
Dead.

Eragrostis major.
Never came up.

Eragrostis neo-mexicano.
Dead.

Eragrostis pilosa.
Dead.

Eragrostis tenulis, A. Gray
Dead.

Erodium cicutarium, Alfilaria.
Never came up.

Euchlaena mexicano.
Dead.

Festuca arundinacea.
1898—
Aug. 3—Fine stand; leaves thick; height, 1.1 m.; cut; weight, cured, 2 lbs., 15.5 oz.
1899—
July 7—Heading along edges of plat.
July 14—Good stand.
Aug. 8—Comparatively few heads for amount of foliage; heads changing color; height, 0.8 m.; cut; weight, green, 3 lbs.; weight, cured, 1 lb., 1.5 oz.
Sept. 26—Second growth about 0.2 m. high; 2.6 tons cured hay per acre.

Festuca fenas.
1898—
Fine stand; an occasional head; forms a thick mat on the ground.

1899—

July 20—Well headed.

July 25—Height, 0.6 m.; fine stand; closely matted: cut; weight, green, 1 lb., 4 oz.; weight, cured, 10 oz.

Sept. 26—Thick second growth; would make fine winter pasture; not high enough to cut, being about 0.2 m.

Festuca ovina arizonica.

1898—

Aug. 3—Poor to fair stand; not headed.

1899—

July 7—Heading on edges of plat.

July 20—Height, 0.65 m.; good stand; cut; weight, green, 12.5 oz.; weight, cured, 7.5 oz.

Sept. 26—Small second growth; 1.1 tons cured hay per acre.

Festuca ovina duriuscula.

1898—

Aug. 3—Good stand; height, 0.3 m.

1899—

June 9—Headed.

July 7—Tips of heads beginning to change color: height, 0.42 m.: weight, green, 1 lb., 2 oz.; weight, cured, 9 oz.

Sept. 26—Second growth forms short, thick mat; 1.3 tons cured hay per acre.

Festuca ovina duriuscula (Second plat).

1898—

Poor to fair stand; forms a thick mat where plants are; an occasional head: height, 0.35 m.

1899—

June 9—Headed.

July 7—Height, 0.4 m.; cut; weight, green, 1 lb., 3 oz.: weight, cured, 8.5 oz.

Sept. 26—Small second growth; 1.3 tons cured hay per acre.

Festuca ovina salcata.

1898—

Aug. 3—Good stand; forms a thick mat; an occasional head; height, 0.37 m.; cut; weight, cured, 6.3 oz.

1899—

June 9—Headed.

July 7—Height, 0.34 m.; same all over plat; length of heads, 0.05 m.; cut; weight, green, 12.5 oz.; weight, cured, 6 oz.

Sept. 26—Small second growth; 0.9 tons cured hay per acre.

Festuca ovina, var. (Europe.)

1898—

Aug. 3—Fair stand; not headed; forms a rather thick mat.

1899—

July 7—Headed; cut; weight, green, 12 oz.; weight, cured, 5 oz.

Sept. 26—Good second growth; 0.7 tons cured hay per acre.

Festuca ovina, L. var.

1898—

Aug. 3—Fair stand; not headed.

1899—

July 7—Headed; changing color; stand thin; mixed with other grasses; height, 0.5 m.; length of heads, 0.075 m.; cut; weight, green, 5 oz.; weight, cured, 4.5 oz.

Sept. 26—Good second growth; 0.6 tons cured hay per acre.

Festuca pratensis.

1898—

Aug. 3—Very good stand; headed and about ripe; height, 0.77 m.; cut; weight, cured, 2 lbs., 11 oz.

1899—

July 7—Heading.

July 25—Height, 0.75 m.; length of heads, 0.17 m.; good stand; cut; weight, green, 2 lbs., 8 oz.; weight, cured, 1 lb.; 2.4 tons cured hay per acre.

Festuca rubra glaucescens.

1898—

Aug. 3—Poor stand; thick mat; starting to head; height about 0.48 m.

1899—

July 7—Headed.

July 14—Grows in thick clumps.

Aug. 8—Changing color; height, 0.45 m.; cut; weight, green, 1.5 lbs.; weight, cured, 10.5 oz.

Sept. 26—Good second growth; 1.5 tons cured hay per acre.

Glyceria aquatica.

Dead.

Glyceria nervata.

Never came up.

Glycine hispida.

Dead.

Glycynliza lepidota.

Never came up.

Hilaria cenchroides.

Dead.

Hilaria jamesii.

Never came up.

Hilaria rigida.

Never came up.

Hordeum adscendens.

Dead.

Hordeum bulbosum.

1898—

Aug. 3—Poor to fair stand; headed; height, 0.89 m.; cut; weight, cured, 9 oz.

1899—

Dead

Hordeum chilense.

1898—

Aug. 4—Poor stand; headed; height, 0.28 m.; cut; weight, cured, 1.8 oz.

1899—

No notes.

Hordeum pratense.

1898—

Aug. 4—Poor stand; headed; height, 0.4 m.; cut; weight, cured, 3.5 oz.

1899—

No notes.

Hosackia purshians.

Never came up.

Koeleria cristata.

1898—

Aug. 4—Poor to fair stand; headed; height, 0.35 m.

1899—

July 7—Headed.

July 25—Height, 0.38 m.; length of heads, 0.09 m.; makes a poor general showing; cut; weight, green, 10.5 oz.; weight, cured, 6 oz.; 0.9 tons cured hay per acre.

Koeleria nitida.

1898—

Aug. 4—Poor stand; headed; height, 0.35 m.

1899—

July 7—Fully headed; height, 0.38 m.

July 20—Cut; weight, green, 8 oz.; weight, cured, 5 oz.

Koeleria valesiaca.

1898—

Aug. 4—Poor stand; only four or five plants; apparently not very thrifty.

1899—

July 7—Headed; height, 0.25 m.; very poor stand; not cut.

Leptochloa imbricata.

Dead.

Lolium perenne.

1898—

Aug. 15—Good stand; well headed; height, 0.65 m.; cut; weight, cured, 1 lb., 1 oz.

1899—

July 24—Very poor stand; a few beginning to head.

Sept. 26—Not over twenty heads in all; fully ripe; height, 0.5 m.; cut; weight, green, 6 oz.; weight, cured, 3.5 oz.

Lycurus phleoides, H. B. K.

Dead.

Lygeum spartum.

Dead.

Melica altissima.

1898—

Aug. 4—Three or four plants; headed; height, 0.45 m.

1899—

July 14—Only four bunches in all; well headed; heads whitening; height, 0.75 m.; was not cut.

Muhlenbergia racemosa.

1898—

Good stand; not headed.

1899—

July 14—Good stand.

Sept. 26—Still green; yellowing from frost; height, 0.5 m.; cut.

Polygonum ramosissimum.

Never came up.

Panicularia aquatica.

1898—

Aug. 4—Poor stand; not thrifty; not headed.

1899—

Dead.

Panicum colonum.

1898—

Aug. 4—One or two plants that may be the species planted.

1899—

July 7—One bunch that may be the species; headed; height, 0.6 m.

Panicum crusgalli.

1898—

Aug. 4—A few plants; not tillered; not headed.

1899—

Dead.

Panicum frumentaceum.

Dead.

Panicum texanum.

1898—

Aug. 8—One plant that may be the species.

1899—
Dead.

Panicum virgatum.
Never came up.

Paspalum dilatatum.
Dead.

Paspalum pubiflorium globrum.
Never came up.

Pencedanium, sp. (*Kooma* from mountains in Persia.)
Never came up.

Phalaris arundinacea.
Never came up.

Phalaris caroliniana, Walt. *(P. intermedia.)*
1898—
Aug. 4—Poor stand; headed and ripening; height, 0.42 m.; cut; weight, cured, 1.5 oz.
1899—
Dead.

Poa arachnifera.
1898—
Aug. 4—One or two plants that may be the species; not headed.
1899—
Dead.

Poa buckleyana.
1898—
Aug. 4—Poor stand; headed; about ripe; height, 0.43 m.
1899—
July 7—Headed.
July 14—Stalks whitening.
July 20—Height, 0.7 m.; fair stand; cut; weight, green, 1 lb., 5 oz.; weight, cured, 10 oz.; 1.5 tons cured hay per acre.

Poa compressa.

1898—

Aug. 4—Good stand; height, 0.35 m.

1899—

July 7—Headed on edges of plat.

July 20—Height, 0.53 m.; good stand; thickly matted at base; cut; weight, green, 1 lb., 1 oz.; weight, cured, 10.5 oz.

Sept. 26—Fairly good second growth; 1.5 tons cured hay per acre.

Poa fertilis.

1898—

Aug. 4—Poor stand; headed; height, 0.7 m.; cut; weight, cured, 8 oz.

1899—

July 7—Heading; poor stand, but matted well in places; leaves grow well up on stem, which would be a good characteristic for hay.

July 25—Height, 0.62 m.; length of heads, 0.24 m.; cut; weight, green, 1 lb., 3 oz.

Sept. 26—Good second growth.

Poa pratensis.

1898—

Aug. 4—Good stand; headed.

1899—

July 7—Headed on edges of plat.

July 20—Height, 0.57 m.; thickly matted at base; cut; weight, green, 1 lb., 1 oz.; weight, cured, 10.5 oz

Sept. 26—Good second growth; 1.5 tons cured hay per acre.

Scirpus atrovirens.

Never came up.

Scirpus martimus.

Never came up.

Secale montanum.

1898—

Aug. 4—Fine stand; headed; height, 1 m.; this plat seems to have more vegetation on it than any in the experiment; cut; weight, cured, 7.8 oz.

1899—

July 14—Headed; good stand.

July 25—Height, 0.85 m.; length of heads, 0.1 m.; cut; weight, green, 4 lbs., 1 oz.; weight, cured, 1 lb., 9.5 oz.

Sept. 26—Good second growth.

Sporobolus asper.

1898—

Aug. 4—Good stand; not headed; height of leaves, 0.7 m.

1899—

Dead.

Sporobolus cryptandrus.

Never came up.

Sporobolus heterolepis.

Never came up.

Sporobolus wrightii.

Dead.

Stipa robusta.

1898—

Aug. 4—Fair stand; headed; height, 1 m.; cut; weight, cured, 14 oz.

1899—

July 14—Fair stand.

Aug. 8—Heading.

Sept. 26—Height, 1 m.; did not head freely; leaves form a thick mat about 0.15 m. high; cut; weight, green, 1 lb.; weight, cured, 10 oz.; 1.5 tons cured hay per acre.

Stipa viridula.

1898—

Aug. 4—Fair stand; heading; height, 0.7 m.; cut; weight, cured, 5.5 oz.

1899—

July 7—Heading.

Aug. 8—Ripe and shattering; seems to be mixed with another variety; height, 0.8 m.; by mistake was not cut until Aug. 21, so heads are badly dried out; weight, green, 1 lb., 6 oz.; weight, cured, 12 oz.; 1.8 tons cured hay per acre.

Thermopsis montana.

Never came up.

Trifolium beckwithi.

Never came up.

Trifolium longipes.

Never came up.

Triticum villosum.

1898—

Aug. 4—Headed and ripening; poor stand; height, 0.6 m.; cut; weight, cured, 6.5 oz.

1899—

Dead.

Vicia villosa.

1898—

Aug. 4—Fine stand; in bloom and pods forming; length of vine, 1.3 m.; cut; weight, cured, 8 lbs.

1899—

Dead.

Zoysia pungens.

Never came up.

LIST OF FORAGE PLANTS WHICH HAVE SHOWN THEMSELVES WORTHY OF FURTHER TRIAL.

Agropyron acutum.
    A. caninum.
    A. divergens.
    A. repens.
    A. richardsonii.
    A. spicatum.
    A. tenerum.
Bromus ciliatus, L.
    B. purgans.
    B. tectorum, L.
Elymus canadensis, L.
    E. canadensis glaucifolius.
    E. giganteus (Europe.)
    E. virginicus, L.
Festuca arundinacea.
    F. fenas.
    F. ovina arizonica.
    F. ovina duriuscula.
    F. ovina salcata.
    F. ovina var. (Europe.)
    F. ovina, L. var.
    F. pratensis.
    F. rubra glaucescens.
Lolium perenne.
Poa buckleyana.
    P. compressa.
    P. fertilis.
    P. pratensis.
Secale montanum.
Stipa robusta.
    S. viridula.
Vicia villosa.

LIST OF FORAGE PLANTS WHICH HAVE BEEN TRIED BUT WHICH HAVE NOT YET FURNISHED SUFFICIENT DATA FROM WHICH TO DETERMINE THEIR USEFULNESS OR USELESSNESS.

Agropyron pseudorepens.
Alopecurus occidentalis.
Andropogon cinhatus.
    A. nutans avenacens.
    A. provincialis, L.
    A. scoparius.
Arrhenatherum elatius, M. & K.
Anthyllis vulneraria, (Kidney Vetch.)
Astragalus carolinianus, L.
    A. crassicarpus, Nut.
Atriplex canescens, James.
    A. halimoides.
    A. leptocarpa.
    A. nummularia.
    A. truncata.
Beckmannia erucaeformis.
Bouteloua eriopoda, Torr.
    B. juncifolia (H. B. K.) Lag.
    B. microstachya.
    B. oligostachya, Torr.
    B. racemosa, Lag.
    B. rothrockii, Vasey.
Bromus adoensis.
    B. carinatus.
    B. unioloides.
Bulbilis dactyloides, Raf.
Calamagrostis canadensis.
    C. confinis.
    C. dubia.
    C. purpurascens.

Calamovilfa longifolia.
Carex straminea.
Chaetochloa glauca.
Chloris elegans.
  C. verticillata.
Dalea alopecuroides.
Dasylirion texanum, Sotol.
Deschampsia caespitosa.
Eatonia obtusata.
Eleusine australis, Scribn.
Elymus glaucus, Buckl.
Emotia lanata, L.
Eragrostis abyssinica, Teff.
  E. purshii.
  E. major.
  E. neo-méxicano.
  E. pilosa.
  E. tenulis, A. Gray.
Erodium cicutarium, Alfilaria.
Euchlaena mexicano.
Glyceria aquatica.
  G. nervata.
Glycine hispida.
Glycynliza lepidota.
Hilaria cenchroides.
  H. jamesii.
  H. rigida.
Hordeum adscendens.
  H. bulbosum.
  H. chilense.
  H. pratense.
Hosackia purshians.
Koeleria cristata.
  K. nitida.
  K. valesiaca.

Leptochloa imbricata.
Lycurus phleoides, H. B. K.
Lygeum spartum.
Melica altissima.
Muhlenbergia racemosa.
Polygonum ramosissimum.
Panicularia aquatica.
Panicum colonum.
  P. crusgalli.
  P. frumentaceum.
  P. texanum.
  P. virgatum.
Paspalum dilatatum.
  P. pubiflorium globrum.
Pencedanium sp. ("Kooma" from mountains in Persia.)
Phalaris arundinacea.
  P. caroliniana, Walt.
Poa arachnifera.
Scirpus atrovirens.
  S. maritimus.
Sporobolus asper.
  S. cryptandrus.
  S. heterolepis.
  S. wrightii.
Thermopsis montana.
Trifolium beckwithi.
  T. longipes.
Triticum villosum.
Zoysia pungens.

LIST OF FORAGE PLANTS WHICH HAVE PROVEN THEMSELVES USELESS UNDER THE CONDITIONS OF CLIMATE AT OUR HIGH ALTITUDE.

Arundinaria macrosperma.
Atriplex semibaccata.
Glycine hispida.
Desmodium tortuosum.
Trifolium incarnatum.
Polygonum sachilense.
Cow pea.
Millet.
Spurrey—Sperglua arvensis.
Serradilla.

Variety Tests of Wheat, Oats and Barley

By B. C. BUFFUM and W. H. FAIRFIELD.

PUBLISHED AS PART OF THE TENTH ANNUAL REPORT OF THE WYOMING EXPERIMENT STATION.

JULY, 1900.

LARAMIE, WYOMING.

Variety Tests of Wheat, Oats and Barley.

BY B. C. BUFFUM AND W. H. FAIRFIELD.

The average altitude of the agricultural land in Wyoming is said to be about 6,000 feet and it is certain that the larger part of the state is more than a mile above the sea. On the high plateaus the season is very short and we early saw the value of finding grain which would produce heavy yields under our conditions and ripen with certainty. The land is fertile and grains succeed admirably if the right varieties are planted. Oats are more extensively grown than any other grains and in order to plant oats it has been necessary for the farmer to purchase whatever was on the market for seed. Very often the variety obtained is a late one and fails to ripen or to more than partially mature a crop. Before the farmer can be sure of the greatest success, he must raise seed at home of kinds which are adapted to the region. In order to aid in doing this, we have given all the varieties which we could obtain, trial at Laramie. In 1896 Professor George Vestal of New Mexico kindly furnished us small amounts of seed of over 400 varieties of wheat, oats and barley. In 1898 Professor A. E. Blount, who had collected grains from all over the world for many years, and who was himself the originator of a number of first-class varieties of wheat and oats, most generously sent us his whole collection. The wheats were planted in the fall, but our winters are too dry for winter grain, and none of this fall planting lived over. We had saved a part of the seed of every variety and it was planted the next spring. We also received in 1896 collections from Professor

R. H. McDowell of Nevada, Professor W. W. Cooke of Colorado, and others. Short rows of the varieties received from New Mexico, Nevada and Colorado were grown on the Experiment Farm in 1896 and 1897 and the collection received from Professor Blount was grown in 1898 and 1899. The results are reported in the following tables, from which the varieties which are most promising for larger field trials may easily be selected.

In 1896 all the wheats, oats, and barleys were planted April 20 to 24; in 1897 on May 1; in 1898 on April 16, and in 1899 on May 6. A killing frost usually occurs about September 10, so that varieties that are not nearly matured at this date do not make a profitable crop.

TABLE I.—*Wheat, 1896.*

This gives the results of wheats grown, from seed furnished by Professor Vestal of New Mexico, during the season of 1896. One row 50 feet long of each variety was planted. The rows were 18 inches apart.

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row	
				feet	*feet*	*lbs.*	*oz.*	*lbs.*	*oz.*
1	Minnesota Fife	July 28	Sept. 14	3.6	0.32	10	14	2	14
2	White Fife	Aug. 8	" 18	3.9	0.35	12	7	3	9
3	Sherman	July 25	" 12	3.7	0.3	14	7	4	5
4	White Russian	" 27	" 17	3.5	0.28	12	1	3	12
5	Odessa		" 14	3.45	0.36	12	12	1	14
6	Eldorado	" 27	" 14	4.0	0.26	8	14	2	5
7	Soft Australian	Aug. 1	" 15	3.85	0.3	8	10	2	15
8	Defiance	July 29							
9	Champion	" 25	" 12	3.7	0.35	14	5	4	1
10	Oregon Club		" 18	3.4	0.26	10	14	3	4
12	Sonora		" 14	3.0	0.3	6	9	2	9
13	White Mexican	" 27	" 18	3.55	0.35	11	7	5	11
14	Improved Fife		" 15	3.6	0.3	10	4	2	7
16	Brooks	Aug. 1	" 16	3.6	0.3	9	5	2	7
17	Rio Grande	July 29	" 14	3.6	0.35	13	3	1	7.5
18	Canada Club	" 23	" 11	3.3	0.27	23	9	5	10
19	Judkin	" 29	" 15	2.65	0.36	10	3	2	10
20	Lost Nation	Aug. 10	" 14	3.75	0.4	13	7	3	6
21	Touzelle		" 12	3.75	0.3	15	7	4	8
22	Australian Club	July 29	" 16	3.75	0.3	13	14	4	11
25	China Tea	" 29	" 16	3.9	0.4	10	6	2	11
26	Chili	" 29	" 18	3.8	0.25	10	12	3	3
28	Egyptian	" 25	" 15	3.9	0.28	13	7	3	12
29	Saxon Fife		Oct. 8	4.0	0.33	10	6	1	15
30	Dominion		" 5	4.0	0.35			1	1
31	Prussian	" 27	Sept 12	3.3	0.25	14	6	4	1

TABLE I (Continued).—*Wheat, 1896.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row	
				feet	*feet*	*lbs.*	*oz*	*lbs.*	*oz.*
32	Golden Drop		Sept. 18	3.8	0.3	15		4	8.5
33	Pringle's No. 6	July 31	" 12	3.6	0.3	13	4	4	
34	" No. 4	Aug. 6	" 17	3.88	0.34	13	6	3	11.
35	" No. 5	" 8	" 14	3.9	0.35	13	3	3	6
38	Fultz	Sept. 16		3.7	0.33				
40	Black Centennial	July 31	" 12	3.9	0.35	14	10	3	9
41	Hedgerow	" 27	" 18	3.4	0.14	12	9	4	7
42	Granite	Aug. 6	" 16	4.0	0.35	12	5	3	13
43	Italian	July 29	" 18	3.85	0.28	12	12	4	
44	New York Flint	Aug. 10	" 17	3.9	0.33	26	2	5	8
45	Bald Baltic	July 29	" 12	3.85	0.3	16	5	5	10
48	Red Orange		" 14	3.7	0.36	14	9	3	7
51	Hybrid No. 10	Aug. 13	" 18	3.8	0.35	15	8	4	12
54	Velvet Chaff		Oct. 8	4.2	0.35	6	14	1	3
55	Turkey	July 29	Sept. 18	3.9	0.3	14		4	1
56	Sardonyx		Oct. 8	4.2	0.4	12	9	1	12
57	Amethyst	" 31	Sept. 15	3.7	0.3	10	1	3	1
58	Ruby		" 18	4.0	0.34	9	6	1	13
62	Emerald								
63	Black Chaff	Aug. 8	" 16	3.4	0.3	10	1	1	8
64	Cretan	July 27	" 18	4.1	0.25	12		3	11
70	Anautka	" 25	" 12	3.6	0.2	11	7	4	3
71	Fountain	Aug. 6	" 18	4.0	0.3	14	3	4	9
72	Palestine	" 6	" 18	4.15	0.35	17	2	4	9
73	White Chaff (smooth)	July 29	" 14	3.7	0.3	14	5	4	7
74	" " (bearded)	" 31	" 12	3.4	0.33	16	4	5	6.5
76	Perfection	Aug. 6	" 23	3.55	0.3	12	15	4	9
77	German Fife	" 8	" 12	4.0	0.4	15	7	4	2
78	Mammoth		Oct. 8	4.0	0.36	9	14	1	7
79	*Triticum								
80	Samara	July 25	Sept. 16	4.5	0.27	11	7	5	4
81	Durum	" 29	" 18	4.1	0.3	14	11	5	3
84	Moscow	" 27	" 18	3.6	0.3	13	3	4	4
85	Knapp	" 29	" 18	3.6	0.27	17	3	5	6
87	Doty	" 27	" 12	3.7	0.3	13	5	3	11
89	White Michigan		" 14	3.36	0.3	11	11	2	5
90	Rickenbrode	Aug. 8	" 16	3.5	0.33	9	6	2	5
91	Red Siberian		" 17	3.5	0.35	17	6	3	11
94	*Rice								
95	*Swamp								
96	*Golden Medal								
97	*Glass								
98	*German Amber			4.26					
99	*Wysor								
100	Dallas		" 15	3.6	0.34	10	9	2	10
101	*Champion Amber								
102	*Finlay		" 26	4.2	0.3				
103	*Lemon								
104	*McGee's Red								
105	*Bennet								
106	*Early May								
107	*Rocky Mountain								
108	*Silver Chaff								
110	Propoe	July 31	" 12	3.7	0.3	13	1	4	
111	*Small Frame								

*This is a winter variety.

TABLE I (Continued).—*Wheat, 1896.*

No.	NAME.	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row	
				feet	*feet*	*lbs.*	*oz.*	*lbs.*	*oz.*
112	*Red Clawson								
113	*Yellow Missouri								
114	*Walker								
116	*Zimmerman								
117	Big May		Oct. 8	4.5	0.3	15		2	8
118	Sardius		Sept. 14	4.6	0.33	8	11	2	1
119	Chrysolite	July 31	“ 18	3.9	0.33	15	6	4	7
120	Beryl	“ 29	“ 16	3.3	0.28	8	9	1	15
122	Jacinth	“ 27	“ 14	3.45	0.35	10	5	3	13
123	Carnelian		“ 23	3.7	0.3	18	2	5	3
124	Agate	“ 23	“ 17	4.0	0.35	10	8	3	5
125	Onyx	Aug. 6	“ 16	3.8	0.3	14	8	4	7
126	Opal		“ 17	3.55	0.3	7	3	5	4
127	Garnet		“ 16	3.8	0.4	9	13	1	11
131	Casaca		“ 17	4.0	0.38	14	4	3	4
132	Califat								
133	Tuscan		“ 15	3.6	0.27	8	15	1	4
134	*Essex								
136	*Pearl								
137	*Hunter's Winter								
138	White Chaff	July 25	“ 18	3.9	0.33	13	2	4	2
139	Square Head Essex								
140	*Gold Drop								
145	Red Oregon Club	Aug. 6	“ 16	3.8	0.27	10	10	3	7
146	Hedgerow	“ 8	Oct. 8	3.9	0.15	11	11	2	14
147	Aowse	July 25	Sept. 16	4.0	0.25	14	11	3	14
148	Monmouth	“ 31	“ 12	4.0	0.35	16	3	4	4.5
149	Russian (Spring)	Aug. 8	“ 14	3.8	0.4	14	1	3	3
150	Vermillion	July 27	“ 14	3.4	0.35	13	13	4	6
151	Smoky	Aug. 8	“ 14	3.7	0.35	15	12	4	11
152	Ed n on Fife		Oct. 8	4.0	0.35	15	11	1	10
153	Nox No. 2	July 29	Sept. 18	3.65	0.35	13	13	5	
154	“ No. 1	“ 29	“ 15	3.7	0.33	6	10	2	6
156	“ No. 3	Aug. 8	“ 16	3.9	0.33	15	2	4	7
157	“ No. 5	July 25	“ 18	3.9	0.45	13	4	4	4
158	Pringle's No. 17		“ 23	3.9	0.4	13	2	3	10
160	Wales	“ 25	“ 18	3.75	0.35	13	1	4	2
162	Northcote's White	Aug. 10	“ 18	3.7	0.33	11		3	8
165	*Cat Mountain			4.0	0.35				
168	Black Chaff	July 31	“ 12	3.9	0.35	14	10	3	9
169	Gneiss	Aug. 8	“ 16	4.1	0.3	13	3	4	4
170	*Velvet Amber								
171	*Hebron		Oct. 8	5.3	0.33				
172	Quartz	July 17	Sept. 12	3.0	0.3	16	3	4	10
173	*White Mediterranean			4.6	0.35				
174	Red “		Oct. 7	3.5	0.3	16	9	2	6
176	Nebraska	“ 27	Sept. 17	4.0	0.33	10	7	2	13
177	White's		“ 12	4.2	0.4	11	10	1	12
178	*Kivet			3.8	0.33				
179	Rust Proof	Aug. 8	“ 16	3.9	0.33	14	13	4	6
180	Baltimore		Oct. 7	4.0	0.25	10	13	1	2.5
181	*Davis								
182	Purple Straw	“ 10	Sept. 16	3.6	0.26	10	2	2	14
183	*Gold Premium								
184½	*			3.7	0.35				

*This is a winter variety.

TABLE I (Continued).—*Wheat, 1896.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row
				feet	*feet*	*lbs.*	*oz.*	*lbs.oz.*
185	*Earnhardt							
186	Wintergreen		Oct. 6	4.6	0.33	7	1	15
187	*St. Ledger							
188	Cheshire							
189	*Hunter's Spring			3.9	0.36			
190	*Oakchott's							
192	Geiger	July 29	Sept. 14	3.35	0.25	10	11	3 4
193	Hornblende	Aug. 8	" 16	4.1	0.35	15	8	4 11
195	Edmenton	" 6	" 12	3.9	0.3	14	2	4 2.5
196	Winnipeg Russian	" 6	" 18	3.9	0.28	10	15	2 15
198	Winnipeg		" 16	4.1	0.23	15	6	5 4
200	Hallett's Pedigree	July 29	" 18	3.8	0.3	16	8	4 10
201	Sibley's No. 1	Aug. 6	" 16	4.4	0.27	7	14	1 5
202	*French Black Chaff			3.7	0.3			
203	Rural	" 6	" 18	4.25	0.3	15	4	4 10
204	Velvet Club		Oct. 7	3.85	0.35	6	8	1 1
207	Whittington		" 8	4.2	0.33	1		9
208	Snowflake	July 31	Sept. 18	3.8	0.3	14		4 2
210	Tagarog	Aug. 8	" 18	4.0	0.33	21	1	6 2
211	*Michigan Amber							
214	*Missouri Turkey			3.0	0.3			
215	* " Mediterranean							
216	*California Walker							
218	*India Red							
219	Andrus Black		Oct. 8	4.2	0.3	17	12	1 7
220	*Mediterranean Hybrid							
221	*Andrus Flint							
222	Saskatchewan	July 3	Sept. 12	3.8	0.35	16	15	4 14
223	Rye	Aug. 6	" 12	4.5	0.35	14	7	2 14
224	Frankenstein	July 31	" 12	3.8	0.35	14	15	4 1
225	March	" 29	" 18	3.75	0.33	12	7	4 9
226	*Flanders		Oct. 7	3.5	0.33			
227	Flourelle		" 7	3.85	0.3	5	13	9
229	Circassian		" 7	3.7	0.3	12	15	1 5
230	White Velvet	" 31	Sept. 18	3.55	0.33	14	1	5 4
231	Verplank		Oct. 7	3.26	0.3	7	4	11
232	*Fenton							
234	Wicker	Aug. 6	Sept. 16	3.45	0.32	9	9	2 14
235	*Hopetown			3.8	0.3			
236	Talavera	" 8	" 17	4.15	0.45	14	9	4 2
238	Shumaker	July 29	" 14	3.6	0.35	13	3	2 1
240	Snake River		Oct. 6	4.0	0.33	13	6	3 4
241	Red River	" 25	Sept. 12	3.5	0.27	9	6	3 2
242	Upland	Aug. 6	" 14	2.85	0.33	9	2	2 7
243	Hard Manitoba	July 27	" 12	3.85	0.3	1	4	12
244	Santa Fe	Aug. 6	" 18	4.1	0.35	9	10	6
247	*Ostery							
249	Democrat							
250	*Buckeye							
251	*Nigger							
252	Armstrong	" 19	Not harvested					
253	Landreth							
254	*Red May							
255	Tasmanian Red							
256	*Wild Goose							

*This is a winter variety.

TABLE I (Continued).—*Wheat, 1896.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 80 feet of row		Yield of grain from 80 feet of row	
				feet	*feet*	*lbs.*	*oz.*	*lbs.*	*oz.*
257	*Treadwell								
259	*Arnold's Hybrid		Sept. 12	3.5	0.3				
260	*Boyer								
261	*Canadian Express								
263	*Emporium								
264	*Hickman								
265	*Lincoln								
266	Michigan Wick		Oct. 8	4.1	2.33	5			14
268	*Powers								
269	*Red Sea								
270	*Roger's								
272	*Scott								
275	*White Rose								
276	*Menomite								
277	*Soule's								
278	*Hungarian								
280	Uxbridge	July 31	Sept. 12	4.1	0.3	1	2		11
283	Rust Proof (soft)	Aug. 10	" 12	3.9	0.3	18	2	4	14
288	Dand Khan No. 2	July 17	" 18	2.5	0.3	4	9	2	
291	*White Mountains								
292	*Fulcaster								
294	*Raub's Prolific								
297	*Crete								
299	*Tappahannock			4.0	0.27				
301	Basalt		Oct. 8	4.3	0.33	9		1	8
302	Flourspar	Aug. 6	Sept. 14	3.8	0.33	10	10	2	8
303	Granite	" 6	" 16	3.65	0.33	8	4	2	
304	Platinum		" 17	3.5	0.27	8	12	1	13
305	Porcelain	" 8	" 18	3.9	0.38	10	6	2	2
306	Silica	July 17	" 12	3.25	0.3	17		6	2
307	Trap		Oct. 8	4.25	0.35	10	5	1	7
309	Pool's Red	Aug. 10	Sept. 17	3.6	0.33	14	1	4	4
310	*Early Rice								
319	Deitz Red		Oct. 8	4.3	0.33	8	15	1	15
321	" Amber		" 7	1.198	0.33	13	15	1	1
328	*Gold Dust								
331	Weeks	" 8	Sept. 17	3.15	0.3	9	11	3	9
332	Hoover		Oct. 7	3.7	0.32	12	14	3	8
333	*Winter Pearl								
334	*Valley			4.3	0.4				
336	Early Oakley		Sept. 18	4.1	0.33	14	2	2	15
337	Genoese	" 6	" 18	3.55	0.35	14	15	4	10
341	*Martin's Amber								
342	Indian	July 31	" 14	3.5	0.25	10	2	3	7
343	*Sheriff (four-rowed)								
344	Baart	" 25	" 12	3.2	0.28	14	15	5	10
347	Ward's Prolific	Aug. 6	" 16	3.4	0.33	8	12	3	5
348	Roseworthy		" 5	1.9	0.25	6	13	2	7
349	Australian Purple Straw	" 10	" 15	3.6	0.3	15	10	4	15
353	*Landreth								
358	Rattling Tom	July 31	" 18	4.0	0 35	14	4	3	10
359	Volo	" 23	" 15	3.8	0.2	12	2	2	15
360	Missogen		Oct. 6	4.15	0.43	12	3	3	5
361	Atlanti	" 17	Sept. 18	3.25	0.2	15	2	6	4
363	Sadoza	" 27	" 16	3.7	0.3	5	15	1	5

*This is a winter variety.

TABLE I (Continued).—*Wheat, 1896.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row	
				feet	*feet*	*lbs.*	*oz.*	*lbs.*	*oz.*
364	Curtis' White	July 27	Sept. 14	3.6	0.35	8	14	2	4
367	*Improved Rice								
368	*Currat's Prolific								
370	*Egyptian No. 1								
386	*Pollard								
387	Russian Hard								
388	*Carter's A								
389	* " B			4.0	0.25				
390	* " C								
391	* " D								
392	* " E								
396	* " I								
397	* " J								
398	* " K								
399	*Northcote's Amber								
400	Algerian No. 1	" 27	" 16	3.95	0.3	11	4	5	8
401	" No. 2	" 25	" 12	3.4	0.2	11	3	4	14
402	" No. 3		Oct, 8	4.4	0.33	12	8	2	1
403	*Reiti		" 8	3.5	0.35				
404	*Galland Hybrid								
405	Zeland		Sept. 17	3.65	0.4	9	14	2	12
406	Lanneurde Mars		" 12	3.7	0.35	11	10	3	
409	Mold's Red			3.4	0.37				
411	*Hungarian			3.25	2.25				
412	Prize	" 25	" 16	3.95	0.27	9	1	2	11
413	Little Wonder		" 18	3.55	0.3	14	10	4	5
414	Champion	" 27	" 17	3.55	0.3	12	13	3	15
416	Oakshot's Champion	" 27	" 16	3.55	0.33	13	15	4	8
417	*Incomparable								
419	McDowell	" 27	" 12	3.6	0.27	16	6	5	8
420	Young's	" 27	" 17	4.0	0.3	19	2	7	10
421	California Red	" 17	" 12	2.85	0.27	9		3	9
422	Little Club	Aug. 8	" 23	3.4	0.17	8	9	3	6
425	Purple		" 12	3.8	0.3	19	7	5	13
426	Tuscan	" 6	" 16	3.8	0.35	9	14	2	15
427	Jubilee	July 25	" 16	3.6	0.35	15	6	4	11
428	Leake's	" 25	" 15	3.75	0.3	12	3	3	12
431	Rodi		" 12	3.0	0.3	12	5	4	8.5
432	Dera		" 14	3.0	0.27	8	10	3	1
433	Baggi	" 25	" 17	2.6	0.23	5	6	2	0
434	Ratti		" 14	3.0	0.25	8		3	1
435	Dorin		" 15	2.6	0.22	9	8	3	8
437	Walu		" 15	2.9	0.25	8	2	3	3
438	Lohi		" 18	3.0	0.25	8	7	2	14
439	Khel	" 25	" 16	2.7	0.26	7	1	3	1
440	Shega	" 22	" 16	3.0	0.28	7	15	3	4
441	Awal No. 1	" 17	" 12	2.9	0.2				
442	" No. 2	" 23	" 18	2.55	0.25	9	11	3	11
444	Archer's Prolific	" 25	" 15	3.0	0.28	10	14	4	8
446	Daub 1	" 27	" 17	4.25	0.3	8	5	2	5
447	Farrie's Durum								
448	Barwick	Aug. 8	" 18	3.26	0.35	13	11	5	1
449	*Early Jasper								
449½	Samara Club		" 14	3.6	0.32	15	14	4	10
450	Bancroft	July 27	" 17	2.75	0.22	7	8	3	6

*This is a winter variety.

TABLE I (Continued). *Wheat, 1896.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row	
				feet	*feet*	*lbs.*	*oz.*	*lbs*	*oz.*
452	Banater	July 27	Sept. 18	3.9	0.24	16	12	1	6
453	Paros	" 27	" 18	3.8	0.23	17	7	5	4
454	Cape	" 31	" 14	3.1	0.25	8	15	2	11
456	Hudson's	" 27	" 12	3.25	0.28	11	10	4	0.5
457	Murray River	Aug. 6	" 18	4.1	0.33	15	7	5	8
458	Green Mountain	July 27	" 16	3.75	0.3	14	13	4	15
460	Cordova		" 17	3.8	0.42	9	14	2	6
461	Little Club		Oct. 6	3.2	0.2	11	1	2	14
463	Carter's 1		" 8	3.9	0.35	17	2	2	6
464	Laird's Prolific	July 27	Sept. 16	3.5	0.3	21	2	3	8
465	Borneo	" 25	" 18	3.9	0.3	13	15	4	12
467	*Veneta			3.7	0.35				
468	*Varlsotta			4.0	0.35				
470	Belolourka	" 25	" 16	4.0	0.23	14	1	4	8
471	Reiti 2		Oct. 6	4.15	0.36	14	4	1	13
472	Bordeaux	Aug. 8	Sept. 16	3.85	0.25	15	4	3	12
478½	Gypsum Fleck		Oct. 6	4.5	0.33	15	14	3	4
481	Northern Champion	" 8	Sept. 16	3.8	0.3	15	7	5	13
498		July 31	" 18	3.9	0.35				7
484			" 12	4.2	0.4	13	5	4	1.5
485		" 27	" 17	3.75	0.35	10	3	3	6
487		Aug. 6	" 17	3.26	0.16	9	15	3	5
492	Frames	" 6	" 17	3.6	0.3	11	12	3	12
495		July 27	" 18	3.2	0.25	10	5	3	4
496		Aug. 8	" 15	3.7	0.33	15	1	2	3
498		July 31	" 18	3.9	0.35				7
499	Large Purple Straw	Aug. 6	" 16	3.9	0.3	11	10	4	5
500		" 10	" 16	3.6	0.35	9	10	2	10
501		" 6	" 18	4.0	0.35	9	8	3	3
503		" 8	" 16	3.5	0.25	8	2	2	6
505		July 29	" 16	3.75	0.3	14	6	4	6
508	*America								
509	*Russian Hard								
511	*Patagonia Trigs								
512	*McCregan								
513	*Farquhar								
514	*Canadian Wonder								
515	*Bearded Monarch								
516	*Badger								
517	Andrus		Oct. 8						
518	*Big English	Aug. 19							
520	*German Emperor								
521	*Lehigh								
522	Lebanon	July 31	Sept. 15	3.75	0.3	12	13	3	12
524	*Rudy		Oct. 7	4.5	0.4				2
525	*Witter								
526	*Wyandot Red			3.15	0.23				
527	*Early Ripe								
528	*Gypsy								
529	*Golden Cross								
530	*Jones' Square Head								
531	*Johnson's								
532	*Longberry								
533	*Miller's Prolific								
534	*Roberts'								

*This is a winter variety.

TABLE I (Concluded).—*Wheat, 1896.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row	Yield of grain from 50 feet of row
				feet	*feet*	*lbs. oz.*	*lbs.oz.*
535	*Smith's White						
537	*Wisconsin Triumph						
538	*Willets.						
539	*Yuva.						
541	*Odessa No. 1.						
542	* " No. 2.						
543	* " No. 3.						
544	* " No. 4.						

*This is a winter variety.

TABLE II.—*Wheat, 1897.*

This gives the results of the second year's trial of all the varieties reported in Table I which matured seed in 1896. One row 50 feet long of each variety was planted. The rows were 18 inches apart.

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row		Weight per bu.
				feet	*feet*	*lbs.*	*oz.*	*lbs.*	*oz.*	*lbs.*
1	Minnesota Fife	July 28	Sept. 28	4.06	0.29	10		2	10	62
2	White Fife	" 28	" 30	3.97	0.31	1	13		15	54.5
3	Sherman	" 22	" 22	3.81	0.25					
4	White Russian	" 20	" 22	3.59	0.25	2	3	1	6	60.5
5	Odessa	" 28	" 21	3.89	0.29	16	10	2	14	60.5
6	Eldorado	" 20	" 24	3.8	0.3	13	5	3	7	58.5
7	Soft Australian	" 28	Oct. 2	4.02	0.36	2	1	1		54
8	Defiance									
9	Champion	" 22	Sept. 23	3.62	0.39	12	12	3	1	57.5
10	Oregon Club	" 28	" 28	3.59	0.3	9	6	1	14.5	57.5
12	Sonora	" 13	Oct. 2	3.55	0.26	1	6		4	49
13	White Mexican	" 28	Sept. 30	4.25	0.29	1	9		12	52.5
14	Improved Fife									
16	Brooks	" 28	" 23	4.2	0.45	13	13	2	15	58
17	Rio Grande	" 22	" 21	3.7	0.37					
18	Canada Club	" 28	" 23	3.6	0.33	8	8	1	1	
19	Judkins	" 20	" 28	3.62	0.33	18	2	3	9	57
20	Lost Nation	" 22	" 28	3.72	0.36	11	14	3	2	59
21	Touzelle	" 20	Oct. 2	3.62	0.27	1	12		13	57.5
22	Australian Club	" 20	Sept. 23	3.6	0.29	10	3	3	4	61.5
25	China Tea	" 22	" 23	3.93	0.3	15	3	3	14	64
26	Chili	" 20	" 23	3.88	0.33	14		3	13	62
28	Egyptian	" 22	" 24	3.75	0.26	12	4	2	14	57.5
29	Saxon Fife	" 22	" 21	3.4	0.33	1	5		15	60.5
30	Dominion	" 28	" 24	3.78	0.31	9	8	2	1	55.5
31	Prussian	" 28	" 29	3.75	0.23	16	7	1	11	50

TABLE II (Continued).—*Wheat, 1897.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row		Weight per bu.
				feet	*feet*	*lbs*	*oz.*	*lbs.*	*oz*	*lbs.*
32	Golden Drop	July 22	Sept. 25			13	8	2	6	59.5
33	Pringle's No 6	" 28	" 29	4.12	0.35	15	1	1	16	51.5
34	" No. 4	" 28	" 29	4.32	0.29	18	2	2	15	53.5
35	" No. 5	" 22	" 29	3.3	0.34	18		2	15	56
38	Fultz	" 28		3.52	0.33					
40	Black Centennial									
41	Hedgerow	" 20	" 25	3.26	0.14	18	15	3	8.5	53.5
42	Granite	" 22	" 25	3.58	0.26	14	9	3	13	57.5
43	Italian									
44	New York Flint	" 22	" 28	3.9	0.3	8	9	2	9	58.5
45	Bald Baltic	" 22	" 22	4.1	0.39	12	10	3	6	61
48	Red Orange	" 22	" 21	4.0	0.37					
51	Hybrid No. 10	" 22	" 25	4.0	0.35	19	14	4	6	57.5
54	Velvet Chaff	Aug. 2		4.07	0.36	1	1		4	43
55	Turkey	July 28	Oct. 2	4.17	0.29	1	8		8	55
56	Sardonyx	Aug. 6	" 2	4.5	0.38	1	4		4	54.5
57	Amethyst									
58	Ruby	" 2	Sept. 29	3.49	0.36	1	9		12	54
59	Jasper	July 22	" 28	4.5	0.35	19	3	3	6	58
62	Emerald									
63	Black Chaff	" 28	" 23	4.0	0.35	15	13	1	14	57
64	Cretan	" 20	" 23	4.07	0.24	11	15	3	1	62
70	Anautka	" 20	" 22	3.58	0.25			2	12	65
71	Fountain	" 22	" 25	3.5	0.33	17	12	4	11	61.5
72	Palestine	" 22	" 28	3.87	0.27	15	12	3	8	59.5
73	White Chaff (smooth)	" 20	" 21	3.55	0.23	1	13	1	2	57.5
74	" " (bearded)	" 22	" 22	3.26	0.25	1	4		11	59
76	Perfection	" 28	" 28	4.27	0.28	17	7	3	6.5	56
77	German Fife	" 22	" 25	3.7	0.4	18		4	1	63
78	Mammoth	" 28	" 28	3.72	0.33	8	11	1	13	58
80	Samara	" 22	Oct. 2	3.4	0.33	1	5		15	60.5
81	Durum	" 22	Sept. 24	3.55	0.18	11	7	3	6.5	60
82	Saratov	" 20	" 21	3.4	0.3	1	9	1		61
84	Moscow	" 28	" 28	3.75	0.28	7	5	2	4.5	60.5
85	Knapp	" 20	" 28	3.62	0.28	17	6	3	5	58
87	Doty	" 20	" 24	3.68	0.31	16	8	2	14	59
89	White Michigan	" 28	" 30	4.14	0.27	1	12		14	56
90	Rickenbrode	" 28	" 21	3.4	0.3					
91	Red Siberian	" 28	" 29	4.14	0.32	1	6		12	56.5
98	German Amber	Aug. 6		3.65	0.3					
100	Dallas	July 31	" 23	4.02	0.3	14	14	2	11	59
102	Finlay	" 28		3.58	0.39					
106	Early May	" 28	" 24	3.4	0.35	2				
107	Rocky Mountain	Aug. 2	Oct. 9	3.58	0.33				4	52
110	Propoe	July 28	Sept. 29	4.3	0.31	22	14	1		54
117	Big May	Aug. 6	Oct. 9	4.15	0.3	5	10		3	47
118	Sardius	" 2	" 2	3.67	0.31	1	9		9	59.5
119	Chrysolite	July 22	Sept. 23	3.5	0.3	14	4	3	5	61.5
120	Beryl	" 28	" 24	3.59	0.26	10		2	2	58.5
122	Jacinth	" 25	" 28	3.65	0.35	10	10	2	8.5	52
123	Carnelian	" 28	" 23	3.75	0.32	12		1	13	
124	Agate	" 22	" 24	3.65	0.23	5	14	1	8	58¼
125	Onyx	" 28	" 28	3.82	0.26	11	1	3	2	56
126	Opal	" 28	" 28	3.97	0.24	11	7	3	8	57
127	Garnet	" 31	" 25	4.14	0.33	18	1	3	9	59
128	Tourmaline	" 28	" 22	3.69	0.18	1	9	1	1	61
131	Casaca	" 31	" 23	4.15	0.33	16	4	2	2.5	

TABLE II (Continued).—*Wheat, 1897.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row		Weight per bu.
				feet	*feet*	*lbs.*	*oz.*	*lbs.*	*oz.*	*lbs.*
133	Tuscan	July 28	Oct. 2	4.6	0.32	1	15		6	55
135	Tuskana			3.36	0.39					
136	Pearl		" 9	4.01	0.29	9	3		11	51
138	White Chaff	" 20	Sept. 30	3.81	0.31	1	13	1		52.5
145	Red Oregon Club	" 28	" 29	3 82	0.29	1	7		9	52.5
146	Hedgerow	" 28	" 25	3.75	0.18	15	8	1	13	
147	Aowse	" 22	" 22	3.82	0.33	13	14	3	14	59.5
148	Monmouth	" 28	" 28	3.88	0.29	11	2	2	7	63.5
149	Russian (spring)	" 20	" 21	4.5	0.37	2	2	1	6	53
150	Vermillion	" 28	" 30	4.07	0.36	2	2			54
151	Smoky	" 28	" 22	4.0	0.3	1	4		12	63.5
152	Edenton Fife									
153	Nox No. 2	" 28	" 28	4.06	0.36	10	6	3	7	50.5
154	" No. 1	" 28	" 28	3.93	0.33	11	4	2	4	60
156	" No. 3	" 22	" 28	3.52	0.32	2	4	1	8	59
157	" No. 5	" 22	" 28	3.72	0.37	11	6	2	14	58
158	Pringle's No. 17	" 28	" 29	4.3	0.34	21	10	3	7.5	52.5
160	Wales	" 28	" 30	4.34	0.33	1			5	54
162	Northcote's White	" 22	" 28	3.48	0.28	5	13	1	10	62
165	Cut Mountain	" 28	" 24	4.1	0.36	8	12	1	3	55.5
166	Red Straw	" 28	Oct. 9	3.52	0.29					
167	Cayaga	" 22	Sept. 23	3.92	0.33	9	2	1	11.5	
168	Black Chaff	" 31	" 23	3.98	0.36	18	1	2	3	59.5
169	Gneiss	" 28	" 25	3.5	0.33	19	4	4	6	58.5
170	Velvet Amber	Aug. 6	Oct. 2	4.4	0.34	1	10		7	54.5
171	Hebron		" 30	3.36	0.36	1	4		7	53
172	Quartz	July 25	Sept. 29	3.65	0.3	1	5		10	52
173	White Mediterranean			3.36	0.26					
174	Red "	" 28	" 29	3.52	0.33					
176	Nebraska	" 20	" 28	3.1	0.3	5		1	1	
177	White's	" 28	" 21	3.94	0.28	1	8		10	57
178	Kivet			4.33	0.39					
179	Rust Proof									
180	Baltimore	" 31	Oct. 9	4.2	0.26	8			3	
182	Purple Straw	" 31	Sept. 29	4.2	0.26	21	4	2	5	51.5
184½		" 28	" 30	4.04	0.33					
186	Wintergreen	Aug. 9		4.11	0.36					
189	Hunter's Spring			3.68	0.36					
192	Geiger	July 20	" 25	3.0	0.28	12	4	3	8	60
193	Hornblende	" 22	" 25	3.52	0.27	17	11	3	12	57.5
195	Edmenton	" 22	" 24	3.26	0.33	13	4	3		61
196	Winnipeg Russian	" 28	" 30	3.91	0.29	1	13		11	54
197	Rust Proof		" 21	3.5	0.3	1	6		13	60
198	Winnipeg	" 28	" 30	4.66	0.29	2	2	1		59
200	Hallett's Pedigree	" 28	" 25	3.78	0.32	17	8	3	8	58
201	Sibley's No. 1	" 22	Oct. 2	4.63	0.24	1	14		5	53
202	French Black Chaff	" 28		3.58	0.33					
203	Rural	" 20	Sept. 29	4.23	0.25	1	7		10	57
204	Velvet Club	Aug. 2		4.76	0.33					
207	Whittington	July 28	" 30	4.4	0.29	1	10		11	53.5
208	Snowflake	" 28	Oct. 2	4.4	0.35	1	12	1		55
210	Tagarog									
213	China Red	" 22	" 9	4.24	0.33	8			15	58
214	Missouri Turkey	Aug. 2	" 9	3.82	0.33	11		1	7	55
216	California Walker	July 28	Sept. 23	3.8	0.35	4	1		4.5	57
219	Andrus Black									
222	Saskatchewan	" 28	Oct. 2	3.91	0.33	1	7		12	58

TABLE II (Continued).—*Wheat, 1897.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row		Weight per bu.
				feet	*feet*	*lbs.*	*oz.*	*lbs.*	*oz.*	*lbs.*
223	Rye		Sept. 29	4.46	0.31	1	13		13	56
224	Frankenstein	July 22	" 25	3.35	0.33	12	3	2	10.5	62
225	March	" 20	" 28	3.42	0.26	7	17	2	10	62.5
226	Flanders			3.42	0.36					
227	Flourelle	Aug. 6		3.72	0.33					
229	Circassian	July 28	Oct. 9	3.91	0.33	6			2	
230	White Velvet	" 28	Sept. 30	4.01	0.27	2		1		53
231	Verplank			3.91	0.39					
234	Wicker	" 28	" 30	3.81	0.23	2		1	2	52.5
235	Hopetown			3.36	0.36					
236	Talavera	" 20	" 21	4.0	0.4					
238	Shumaker	" 22	Oct. 2	4.21	0.33	1	11		15	58
240	Snake River	" 28	" 2	4.07	0.35	1	12	1		57.5
241	Red River	" 20	Sept. 29	3.49	0.29	1	11		11	48.5
242	Upland	" 28	Oct. 2	4.27	0.29	1	10		14	54
243	Hard Manitoba	" 28	Sept. 26	3.91	0.31	18	9	3	3	57.5
244	Santa Fe	" 28	" 29	4.17	0.29	2	1	1	1	56.5
252	Armstrong									
255	Tasmanian Red	Aug. 18		4.08	0.48					
257	Treadwell	July 28		4.72	0.39					
259	Arnold's Hybrid									
266	Michigan Wick									
268	Powers	" 22		3.36	0.3					
280	Uxbridge	" 31	Oct. 2	4.2	0.29	1	8		13	52
283	Rust Proof (soft)	Aug. 22	Sept. 21	3.5	0.33	1	14	1	3	61.5
288	Dand Khan No. 2	July 20	" 23	2.6	0.26	8	12	2	12	63
290	Niagara	" 22	" 28	4.0	0.4	9	4	2	2	61.5
292	Fulcaster	" 31		3.48	0.26					
299	Tappahannock	Aug. 6		4.24	0.37					
301	Basalt	July 28	Oct. 9	4.1	0.36	7	6	1		51.5
302	Flourspar	" 28	Sept. 25	3.4	0.3	15	14	4	3	61
303	Granite	" 22	" 25	3.55	0.29	16	4	4	10	57.5
304	Platinum	" 28	" 29	4.07	0.29	15	9	2	10	50.5
305	Porcelain	" 28	" 21	4.4	0.31	17	6	2	14	57.5
306	Silica	" 22	" 22	3.85	0.33	1	9		11	61.5
307	Trap	" 28	Oct. 2	4.05	0.3	1	8		10	53
309	Pool's Red	" 28	Sept. 29	4.14	0.31	17	7	2	14	55
319	Deitz Red	" 28	" 24	3.56	0.32	14	2	2	3.5	58.5
321	" Amder	Aug. 6		3.72	0.27					
331	Weeks	July 28	" 30	4.21	0.29	2	3	1	2	54
332	Hoover		" 25	3.7	0.33	15	8	2	13	
334	Valley	Aug. 9		3.57	0.44					
336	Early Oakley	July 28	" 24	3.5	0 3	15	5	5	8.5	57
337	Genoese									
342	Indian	" 22	" 28	3.75	0.38	14	8	3		60
344	Baart	" 20	" 24	3.7	0.29	11	8	3	8	59
347	Ward's Prolific	" 20	" 30	4.34	0.43	2	4	1	4	59
348	Roseworthy		" 21	2.0	0.22					
349	Australian Purple Straw	" 22	" 22	3.8	0.25	13	8	3	10	61.5
355	Du Toits	" 20	" 24	3 26	0.26	12	10	3	4	59
358	Rattling Tom	" 22	" 29	4.0	0.33	1	11		10	53
359	Volo	" 20	" 30	4.14	0.21	2	2		13	54.5
360	Missogen	" 20	" 28	3.68	0.32	8	6	2	14.5	60.5
361	Atlanti	" 22	" 24	3.81	0.21	9	11	2	9	57
363	Sadoza									
364	Curtis' White	" 22	" 23	3.98	0.39	11	7	2	10.5	59
365	Seven Headed Red	" 22	Oct. 2	4.11	0.31	2		1	4	58

TABLE II (Continued).—*Wheat, 1897.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row		Weight per bu.
				feet	*feet*	*lbs.*	*oz.*	*lbs.*	*oz.*	*lbs.*
366½		July 20	Sept. 30	3.78	0.2	1	12	1		53
389	Carter's B			5.26	0.26					
396	“ I	July 31	Sept. 23	4.0	0.35	17	4	1	8	
397	“ J	Aug. 2	Oct. 9	3.81	0.42	4			5	
398½				3.78	0.33					
400	Algerian No. 1	July 28	Sept. 24			9	9	1	4	61
401	“ No. 2	“ 20	“ 22	3.08	0.22	6	4	2	0	
401½		“ 22	“ 30	3.39	0.2	2	2	1	1	58
402	“ No. 3	“ 31	Oct. 9	3.78	0.35	4			2	49
402½		Aug. 6	“ 9	4.24	0.33					
403	Reiti			3.59	0.42					
405	Zeland	July 31	Sept. 30	4.44	0.37	1	3		8	55
406	Lanneurde Mars	“ 28	“ 28	3.75	0.33	11	4	1	12	56
409	Mold's Red	“ 28	“ 28	4.0	0.3	8	8	2	1	60.5
411	Hungarian	“ 28	“ 25	3.88	0.35	15	7	1	7	55.5
412	Prize	“ 22	“ 29	3.45	0.26	17	6	4	9	55.5
413	Little Wonder	“ 22	“ 28	3.49	0.21	12	15	4	2	58.5
414	Champion	“ 22	“ 23	3.62	0.25	10	4	1	10	
416	Oakshot's Champion	“ 22	“ 28	3.85	0.28	11	12	2	13	60.5
419	McDowell	“ 22	“ 28	3.69	0.29	12	10	3	4	62
420	Young's	“ 20	“ 21	3.75	0.23	2	4	1	7	58.5
421	California Red	“ 20	“ 23	2.65	0.29	9	11	2	2	57
422	Little Club	“ 22	“ 28	3.7	0.2	8	11	2	8	53.5
425	Purple									
426	Tuscan	“ 28	Oct. 2	4.46	0.29	1	12		14	55
427	Jubilee	“ 20	Sept. 28	3.88	0.3	10	6	1	11	48.5
428	Leake's	“ 28	“ 28	3.55	0.25	10	14	3	2	61.5
431	Rodi	“ 20	“ 29	2.9	0.27	1	11		9	50
431½		“ 20	“ 21	2.45	0.26					
432	Dera									
433	Baggi	“ 20	“ 22	2.53	0.23	9	2	3	4	65
434	Ratti	“ 20	“ 29	3.26	0.24	1			4	52
435	Dorin	“ 20	“ 28	2.96	0.18	9	8	2	5	56.5
437	Walu	“ 13	“ 30	3.68	0.23					51
438	Lohi	“ 20	“ 28	3.35	0.21	6	13	2	2	57
439	Khel	“ 23	“ 30	3.5	0.22	1	4		7	51
440	Shega	“ 20	“ 22	3.26	0.26		13		7	57
441	Awal No. 1	“ 20	“ 28	3.39	0.21	9	11	2	11	55.5
442	“ No. 2	“ 20	“ 28	3.16	0.26	10	13	8	13	53.5
444	Archer's Prolific	“ 20	“ 22	3.2	0.25	9	9	2	15	60.5
446	Daub I	“ 25	“ 23	3.98	0.29	10	12	2	3	
447	Farrie's Durum									
448	Barwick	“ 22	“ 23	3.5	0.33	14	2	2	12	54
449½	Samara Club	Aug. 13	Oct. 2	4.24	0.3		10		3	54
450	Bancroft	July 20	Sept. 22	3.15	0.2	6	12	2	2	56.5
452	Banater	“ 28	“ 24	3.85	0.24	9	14	3	8	58
453	Paros	“ 22	“ 28	4.04	0.24	12	8	3	3	57
454	Cape	“ 20	“ 23	3.33	0.27	15	1	4	3	59
456	Hudson's									
457	Murray River	“ 28	“ 28	3.3	0.33	4	8		8	
458	Green Mountain	“ 22	“ 25	3.62	0.31	15	9	3	8	55.5
460	Cordova	“ 22	“ 23	3.8	0.37	10	8	1	8	
461	Little Club	“ 20	“ 28	3.08	0.13	11	3	2	12	58
463	Carter's I	Aug. 2	“ 23	4.0	0.42	15	14	1	15	56
464	Laird's Prolific	July 28	“ 28	3.88	0.27	13	12	3	8	56.5
465	Borneo	“ 20	“ 23	3.9	0.3	12	8	3	3	57.5
467	Veneta			4.42	0.45					

TABLE II (Continued).—*Wheat, 1897.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row		Weight per bu.
				feet	*feet*	*lbs.*	*oz.*	*lbs.*	*oz.*	*lbs.*
468	Varlsotta	July 31	Oct. 2	4.4	0.39		7			48
470	Belolourka	" 28	Sept. 24	4.3	0.23	11	6	2	9.5	53.5
471	Reiti 2	Aug. 2	Oct. 9	4.2	0.37	1	3		4	55
472	Bordeaux	" 2	Sept. 24	4.3	0.3	14	7	1	4	53
478½	Gypsum Fleck	July 20	" 25	4.24	0.37	21	10	2	2	52
481	Northern Champion	" 22	" 28	3.7	0.28	6	12	1	10	
483		" 22	Oct. 2	3.7	0.27					
484		" 22	Sept. 25	3.85	0.33	14	15	4	0	58.5
485		" 20	" 24	3.62	0.09	14	11	2	8	57
492	Frames	" 22	" 25	3.26	0.3	12	15	3	4	60
495		" 22	" 25	3.88	0.29				6	53
498		" 28	Oct. 2	4.24	0.33				5	59
499	Large Purple Straw	" 22	Sept. 28	3.29	0.24	8	12	3	10	60.5
500		" 20	" 28	3.58	0.33	16	8	3	8	58
501		" 22	" 30	4.4	0.36	1	2			56
503		" 28	" 28	3.81	0.31	13	6	2	4	57.5
505		" 22	" 29	3.78	0.31	1	6		10	53.5
525	Purple	" 28	" 29	3.26	0.26	21	4	2	8	
526	Wyandot	Aug. 9	Oct 9	3.91	0.31				2	54
540		July 28	Sept. 28	4.14	0.33					59
543	Odessa No. 3			3.94	0.37					
544	" No. 4			3.0	0.39					

TABLE III.—*Wheat, 1898.*

This gives the results of the first year's trial of Professor Blount's collection of wheats. The varieties reported on in Tables I and II were originally from Professor Blount, but the varieties reported in the following table were grown from seed selected by him personally and furnished gratis to the Station. One row ten feet long of each variety was planted. The rows were 20 inches apart.

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row	Weight per bu.
				feet	*feet*	*oz.*	*lbs.*
1	Minnesota Fife	July 19	Aug. 29	3.4	0.36	12	60
2	White Fife	" 23	Sept. 9	2.96	0.33	8	57.5
3	Sherman	" 14	Aug. 27	2.84	0.15	16	63
4	White Russian	" 14	" 27	3.1	0.36	14	63.5
5	Odessa	" 14	Sept. 9	3.65	0.33	5	58
6	Eldorado	" 12	" 6	3.29	0.27		
7	Soft Australian	" 14	" 2	3.0	0.35	10	60
8	Defiance	" 14	" 2	3.55	0.36	15	59.5
9	Champion	" 14	" 2	3.26	0.36	14	60
10	Oregon Club	" 14	" 6	3.29	0.33	5.5	52
11	Hard Australian	" 19	" 6	3.85	0.38	8	51.5
12	Sonora	" 12	" 2	2.67	0.6	8	61.5
13	White Mexican	" 12	" 6	3.3	0.35	12	57.5
14	Improved Fife	" 19	" 6	3.26	0.39	8	57
15	Russian	" 19	" 2	3.14	0.39	8.5	57.5
16	Brooks	" 19	" 9	3.2	0.47	7	54
17	Rio Grande	" 14	Aug. 28	3.34	9.4	16	63
18	Canada Club	" 19	Sept. 2	2.84	0.3	14	62
19	Judkin	" 19	" 9	2.96	0.43	8	57
20	Lost Nation	" 19	" 6	3.29	0.34	6	54
21	Touzelle	" 12	Aug. 27	2.9	0.27	9	63
22	Australian Club	" 14	" 29	2.67	0.3	11	58.5
23	Golden Globe	" 23	Sept. 9	3.1	0.41	11	60
24	Mediterranean Spring	" 23	" 9			9	58
25	China Tea	" 19	" 3	3.2	0.46	9	62
26	Chili	" 12	" 3	2.37	0.33	11	59
27	China Spring	" 19	" 9	3.28	0.41	7	52.5
28	Egyptian	" 12	" 6	3.39	0.3	6	60
29	Saxon Fife	" 23	" 9	3.0	0.36	8	56.5
30	Dominion	" 23	" 3	3.1	0.33	10	50
31	Prussian	" 19	" 3	2.87	0.27	9	61
32	Golden Drop	" 19	" 3	2.67	0.25	11	61.5
33	Pringle's No. 6	" 19	" 6	3.0	0.33	6.5	50
34	" No. 4	" 23	" 9	3.16	0.35	6	54
35	" No. 5	" 19	" 6	3.1	0.33	7.7	56
36	Winter Australian	" 23	" 6	3.23	0.36	7.5	52.5
38	Fultz	" 19	" 9	2.96	0.35		
39	Midge Proof	" 23	" 6	2.81	0.3	6	48
40	Black Centennial	" 19	" 6	2.74	0.32	9	56
41	Hedgerow	" 19	Aug. 31	2.55	0.16	12	60.5
42	Granite	" 19	Sept. 6	2.87	0.34	9.5	58
43	Italian	" 12	" 6	3.13	0.74	11	62.5
44	New York Flint	" 19	" 6	2.9	0.32	4	53.5
45	Bald Baltic	" 19	" 6	2.7	0.35	6.5	57
47	Illinois Second Premium	Aug. 12	" 12	3.2	0.35		
48	Red Orange	July 19	Aug. 29	3.2	0.39	13	60
50	Perkey	" 12	" 29	2.96	0.23	9	62
51	Hybrid No. 10	" 23	Sept. 9	2.67	0.34	9	57
52	Golden Chaff	" 14	Aug. 29	3.0	0.34	12	59
53	Mediterranean Red Chaff	" 23	Sept. 6	2.97	0.3	8	58
54	Velvet Chaff	" 23	" 9	3.2	0.39	8	54.5
55	Turkey	" 19	" 6	2.87	0.27	5.5	56

*This is a winter variety.

TABLE III (Continued).—*Wheat, 1898.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row	Weight per bu.
				feet	*feet*	*oz*	*lbs.*
56	Sardonyx	July 28	Sept. 6	2.9	0.33	7.5	58
57	Amethyst	" 23	" 6	3.16	0.33	8.5	58
58	Ruby	" 28	" 9	2.8	0.36	7	54
59	Jasper	" 19	" 6	3.2	0.39	10	57.5
60	Sapphire	" 19	" 6	2.9	0.41	8.5	53.5
61	Chalcedony	" 19	" 6	2.94	0.3	12	52
62	Emerald	" 19	" 6	3.26	0.46	4	54
63	Black Chaff	" 23	" 9	2.94	0.36	6	58
64	Cretan	" 15	Aug. 29	3.2	0.26	8	63
65	Andriola Red	" 19	" 31	2.66	0.33	8	62.5
66	" Amber	" 19	" 29			11	62.5
67	Purple Chaff	" 14	Sept. 6	2.9	0.18	11	60
68	Boughton	" 19	" 9	3.13	0.18	11	59.5
70	Anautka	" 12	Aug. 29	3.6	0.2	12	65
71	Fountain	" 19	" 26	3.0	0.3	10	55.5
72	Palestine	" 23	Sept. 6	3.35	0.43	9	56.5
73	White Chaff (smooth)	" 23	" 6	2.85	0.26	13	59
74	" " (bearded)	Never came	up				
76	Perfection	" 19	" 9	2.83	0.35	13	56.5
77	German Fife	" 19	" 6	3.26	0.36	9.5	58
78	Mammoth	" 23	" 9	3.16	0.33	7	52
79	*Triticum	Aug. 31					
80	Samara	July 19	" 9	3.43	0.24	8	59
81	Durum	" 19	" 9	3.43	0.24	5	59
82	Saratov	" 23	" 9	2.96	0.35	6	56
83	Ames	" 19	" 9	3.43	0.24	9	61
84	Moscow	" 23	" 9	2.96	0.35	5	60
85	Knapp	" 19	" 9	2.96	0.35	9	59
86	Scotch Fife	" 23	" 9	3.13	0.35	8	56.5
87	Doty	" 14	Aug. 29	2.88	0.86	12	65
88	Meekins	" 14	Sept. 6	3.36	0.41	4	63
89	White Michigan	" 28	" 9	3.03	0.33	4	57
90	Rickenbrode	" 23	" 9	3.30	0.32	8	54.5
91	Red Siberian	" 19	" 9	3.29	0.35	9	54.5
92	*Heige's Prolific						
94	*Rice						
96	*Gold Medal						
97	*Glass						
98	*German Amber	Aug. 12					
99	*Wysor	" 23					
100	Dallas	July 23	" 6	3.2	0.34	11	58.5
101	*Champion Amber	Aug. 12					
102	Finlay	" 12	" 15	3.33	0.35	5	45
103	*Lemon						
104	*McGee's Red	" 4					
105	*Bennet	" 12					
106	*Early May	" 30					
107	*Rocky Mountain	" 4					
108	*Silver Chaff	" 23					
109	*Blue Stem						
110	Propoe	July 19	Oct. 29	2.7	0.3	17.5	59.5
111	*Small Frame	Aug. 23					
112	Red Clawson	July 28	Sept. 15	3.03	0.33	3	50
113	*Yellow Missouri						
114	*Walker						

*This is a winter variety

TABLE III (Continued).— *Wheat, 1898.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row	Weight per bu.
				feet	*feet*	*oz.*	*lbs.*
116	*Zimmerman						
117	Big May	July 19	Sept. 12	3.52	0.33	8	54.5
118	Sardius	" 19	" 6	3.58	0.35	11.5	60
119	Chrysolite	" 14	Aug. 31	3.0	0.35	17.5	58
120	Beryl	" 14	" 31	3.03	0.3	12.5	59.5
121	*Topaz	" 14					
122	Jacinth	" 14	" 29	3.2	0.3	16	60
123	Carnelian	" 19	Sept. 6	2.87	0.29	9	53.5
124	Agate	" 19	" 6	2.87	0.29	9	56
125	Onyx	" 14	" 6	2.87	0.29	13	54
126	Opal	" 19	" 6	2.87	0.29		
127	Garnet	" 19	" 7	3.0	0.36	6	57
128	Tourmaline	" 23	" 7	2.83	0.22	8	59
129	Felspar	" 19	" 7	2.83	0.34	9	51.5
131	Casaca	" 28	" 10	3.1	0.4	6	56
133	Tuscan	" 19	" 7	3.32	0.34	7	57.5
134	*Essex	Aug. 12					
135	Tuskana	" 12	" 15	3.33	0.31	3	42
136	*Pearl	" 4					
137	*Hunter's Winter	" 23					
138	White Chaff	July 19	" 7	2.94	0.31	11	55.5
140	*Gold Drop	Aug. 30					
145	Red Orange Club	July 23	" 12	2.84	0.28	8	52
146	Hedgerow	" 28	" 12	2.74	0.14	8	53.5
147	Aowse	" 28	" 7	3.39	0.32	15	53.5
148	Monmouth	" 19	" 7	3.26	0.4	8	58
149	Russian (Spring)	" 23	" 7	3.0	0.4	7	56.5
150	Vermillion	" 23	" 7	3.26	0.42	7	56
151	*Smoky	" 23					
152	Edenton Fife	" 23	" 7	3.26	0.33	6	50
153	Nox No. 2	" 19	" 12	3.2	0.35	9	50
154	" No. 1	" 23	" 10	3.26	0.37	9	55.5
155	" No. 4	" 19	" 7	3.26	0.42	8	57
157	" No. 5	" 19	" 10	3.29	0.41	12	54.5
158	Pringle's No. 17	" 19	" 10	3.03	0.36	8	54
159	" No. 18	" 23	" 10	3.2	0.39	8	51
160	Wales	" 19	" 10	2.9	0.36	9	56
161	Dead Sea	Aug. 12	" 15	2.8	0.3	0.5	42
162	Northcote's White	July 23	" 10	3.03	0.35	11	54
163	" Amber	" 19	" 7	3.0	0.35	8	53.5
164	White May	" 14	" 7	2.8	0.33	11	59
165	Cat Mountain	" 23	" 15	3.1	0.36	2	52.5
166	Reed Straw	Aug. 4	" 15	3.29	0.33	3	54
167	Cayaga	July 19	" 7	3.4	0.4	12.5	59.5
168	Black Chaff	" 28	" 12	3.2	0.4	7	56
169	Gneiss	" 23	" 12	3.2	0.3	12	50
170	*Velvet Amber	Aug. 12					
171	Hebron	July 28	" 15	4.88	0.26		
172	Quartz	" 12	" 10	2.96	0.36	12	59.5
173	*White Mediterranean	Aug. 17	" 19	3.72	0.38		
174	Red "	July 19	" 12	3.39	0.28	4	53
175	French Imperial	" 28	" 17	4.18	0.35	8	48.5
176	Nebraska	" 12	Aug. 29	3.3	0.29	15	62
177	White's	" 19	Sept. 7	3.58	0.35	10.5	60
178	*Kivet	" 28	" 15	3.7	0.35	2	45

*This is a winter variety.

TABLE III (Continued).—*Wheat, 1898.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row	Weight per bu.
				feet	*feet*	*oz.*	*lbs.*
179	Rust Proof	July 19	Sept. 10	3.52	0.32	15	59.5
180	*Baltimore	Aug. 4					
181	*Davis						
182	Purple Straw	July 19	" 7	3.1	0.27	8	60
183	*Gold Premium	Aug. 17					
184	*Hick's Prolific	" 4					
185	*Earnhardt	" 17					
186	*Wintergreen	" 4					
187	*St. Ledger	" 12					
188*a*		July 19	" 7	3.26	0.35	13	58
188*b*		" 12	Aug. 29	3.0	0.33	16	60
188*c*		" 12	Sept. 7	3.0	0.30		
189	Hunter's Spring	Aug. 4	" 19	3.58	0.36	2	48
190	*Oakchott's	" 27					
191	Hardwick	July 12	Aug. 31	3.05	0.35	19	62.5
192	Geiger	" 12	" 29	3.1	0.33	11	62
193	Hornblende	" 14	Sept. 7	3.26	0.36	13	59
194	Sea Island	" 19	" 12	3.45	0.4	6	63
195	Edmenton	" 19	" 7	3.59	0.42	12	59
196	Winnipeg Russian	" 19	" 7	3.4	0.35	13.5	57.5
197	Manitoba	" 23	" 13	3.29	0.36	12	60
198	Winnipeg	" 12	" 10	3.45	0.25	12	61
199	Russian White	" 19	" 7	3.26	0.35	10	58
200	Hallett's Pedigree	" 23	" 13	3.29	0.68	7	53
201	Sibley's No. 1	" 19	" 10	3.88	0.27	10	55
202	*French Black Chaff	Aug 12					
203	Rural	July 19	" 10	3.88	0.27	7	52
204	*Velvet Club	Aug. 17					
205	Austrian	July 19	" 10	3.03	0.3	12	56
206	Bohemian	" 28	" 20	3.68	0.28	3	49
207	Whittington	" 19	" 7	2.94	0.3	9	56.5
208	Snowflake	" 19	" 10	3.23	0.32	8	56
209	Beardless Velvet	" 19	" 10	2.96	0.3	12	52
210	Tagarog	" 19	" 10	3.1	0.31	9	61
211	*Michigan Amber	Aug. 23					
212	China White	July 14	Aug. 29	2.85	0.26	11	59.5
213	" Red	" 12	" 29	2.7	0.27	8.5	61
214	Missouri Turkey	" 28	Sept. 20	3.26	0.31	6	58
215	* " Mediterranean	Aug. 4					
216	California Walker	" 4	" 20	3.35	0.31	4	50
218	*India Red	" 23					
219	Andrus Black	July 19	" 13	3.26	0.32		
220	*Mediterranean Hybrid						
221	*Andrus Flint						
222	Saskatchewan	" 19	" 7	3.58	0.3	11	58
223	Rye	" 23	" 7	4.1	0.33	12	56.5
224	Frankenstein	" 23	" 10	3.30	0.32	10	56
225	March	" 14	" 7	3.26	0.3	12	58
226	Flanders	Aug. 4	" 20	3.75	0.33	2	44
227	*Flourelle	" 4					
228	Victoria	July 19	Sept. 13	3.2	0.38	5	52
229	*Circassian	Aug. 4					
230	White Velvet	July 14	" 7	3.2	0.28	16	56
231	Verplank	Aug. 4	" 19	3.43	0.35	2	48
232	*Fenton	" 4					

*This is a winter variety.

TABLE III (Continued).—*Wheat, 1898.*

No.	NAME.	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row	Weight per bu.
				feet	*feet*	*oz.*	*lbs.*
233	Sandomirk	July 14	Sept. 10	3.43	0.24	14	64
234	Wicker	" 19	" 10	3.26	0.3	1	53.5
235	Hopetown	Aug. 4	" 20	3.58	0.32		
238	Shumaker	July 14	" 7	3.7	0.4	8	58
240	Snake River	" 23	" 12	3.43	0.35	7	56
241	Red River	" 14	" 7	3.1	0.33	12	59
242	Upland	" 23	" 12	3.2	0.35	8	55
243	Hard Manitoba	" 23	" 12	3.2	0.35	4	53
244	Santa Fe	" 19	" 12	3.48	0.3	12	52.5
247	Ostery	" 23	" 13	3.16	0.35		
250	*Buckeye	Aug. 27					
251	*Nigger	" 4					
252	*Armstrong	" 17					
253	*Landreth						
254	*Red May	" 14					
255	*Tasmanian Red	" 12					
256	*Wild Goose	" 23					
257	*Treadwell	" 23					
259	*Arnold's Hybrid	" 23					
260	*Boyer	" 17					
261	*Canadian Express	" 12					
272	*Scott	" 12					
275	*White Rose	" 12					
276	*Menomite	" 12					
277	*Soule's	" 23					
278	*Hungarian	" 12					
280	Uxbridge	July 23	" 8	3.26	0.3		
283	Rust Proof (soft)	" 23	" 8	3.26	0.33	8	56
288	Dand Khan No. 2	" 5	Aug. 29	2.9	0.38	11	64
290	Niagara	" 19	Sept. 8	3.26	0.36	6	53
291	*White Mountains						
292	*Fulcaster	Aug. 4					
293	*German Emperor	" 23					
294	*Raub's Prolific	" 27					
297	*Crete	" 23					
299	*Tappahannock	" 4					
300	Gypsum	July 23	" 12	3.33	0.34	13	55.5
301	Basalt	" 28	" 8	3.91	0.36	9	55
302	Flourspar	" 23	" 8	3.72	0.35	13	56.5
303	Granite	" 23	" 8	3.39	0.33	14	57.5
304	Platinum	" 23	" 8	3.58	0.35	10	56
305	Porcelain	" 23	" 8	3.45	0.4	16	56
306	Silica	" 19	" 8	3.4	0.33	19	58.5
307	Trap	" 23	" 8	3.52	0.28	12	57.5
309	Pool's Red	" 23	" 8	3.46	0.35	15	57
310	*Early Rice	Aug. 23					
319	Deitz Red	July 23	" 12	3.33	0.31	8	55
321	" Amber	Aug. 4	" 20	3.72	0.3	1	46
322	Dayton	July 23	" 15	3.39	0.33	4	54
323	Rochester	" 28	" 12	3.9	0.33	8	53
328	*Gold Dust	Aug. 23					
330	*Jennings						
331	Weeks	July 19	" 8	3.2	0.3	16	58
332	Hoover	" 23	" 8	3.58	0.35	9	57.5
333	*	Aug 23					

*This is a winter variety.

TABLE III (Continued).—*Wheat, 1898.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row	Weight per bu.
				feet	*feet*	*oz*	*lbs.*
334	*Valley	Aug. 12					
336	Early Oakley	July 23	Sept. 12	3.58	0.35	8	57.5
337	Genoese	" 23	" 8	3.26	0.33	13	57.5
339	*Egyptian Flint						
341	*Martin's Amber						
342	Indian	" 19		3.26	0.36	12	60
343	Sheriff (four-rowed)	" 12	Aug. 29	2.8	0.26	15	64.5
344	Baart		Sept. 8	3.26	0.33	14	59.5
347	Ward's Prolific	" 19	" 8	3.26	0.4	10	60.5
348	Roseworthy	" 5	Aug. 29	2.2	0.27	12	62.5
349	Australian Purple Straw	" 14	Sept. 8	3.58	0.33	19	57.5
350	" Indian	" 2	Aug. 29	2.0	0.25	14	63
354	*Sibley's Golden	Aug. 23					
355	Du Toits	July 12	Sept. 8	3.26	0.33	18	58.5
357	Steinwedel's Early	" 14	" 8	3.26	0.28	13	58
358	Rattling Tom	" 14	" 8	3.45	0.3	11	57
359	Volo	" 12	" 8	3.57	0.2	14	60.5
360	Missogen	" 23	" 12	3.52	0.39	7	50.5
361	Atlanti	" 12	" 8	3.39	0.2		
362	*Reliable	Aug. 4					
363	Sadoza	July 19	" 8	3.26	0.33	6	54
364	Curtis' White	" 19	" 8	3.46	0.38	10	56
365	Seven Headed Red	" 19	" 8	3.75	0.27	10	54.5
366	Ontario	" 12	" 8	3.2	0.18	12	60
366½		" 12	" 8	3.26	0.23	11	50.5
367	*Improved Rice	Aug. 4					
368	*Currat's Prolific						
369	*Mealy	" 23					
370	*Egyptian No. 1	" 17					
383	" F	July 19	" 8	3.58	0.33	8	55.5
386	*Pollard						
388	*Carter's A	Aug. 17					
389	" B	" 12	" 20	3.85	0.22	2	38
390	* " C	" 17					
391	* " D	" 12					
392	* " E	" 17					
393	" F	" 4	" 15	3.35	0.39	2	42
394	* " G	" 12					
395	* " H	" 12					
397	* " J	" 23					
398	" K	" 17	" 20	3.65	0.26	1	36
398½		" 12	" 20	3.11	0.31	3	40
399	*Northcote's Amber	" 27					
400	Algerian No. 1	July 12	" 8	3.26	0.23	24	60.5
401	" No. 2	" 12	" 8	3.26	0.23	22	62.5
401½		" 12	" 8	3.26	0.21	19	62
402	" No. 3	" 12	" 8	3.58	0.28	12	60.5
402½		" 28	" 15	4.24	0.3	6	49
403	*Reiti	Aug. 12					
404	Galland Hybrid	" 4	" 15	4.24	0.3	2	45
405	Zeland	July 23	" 12	3.91	0.39	11	57
406	Lanneurde Mars	" 19	" 8	3.5	0.33	8	56
407	Berthoud	" 28	" 5	4.24	0.3	9	51.5
408	Mold's White	Aug. 12	" 15	3.52	0.33	1	40
409	* " Red	" 27					

*This is a winter variety.

TABLE III (Continued).—*Wheat, 1898.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row	Weight per bu.
				feet	*feet*	*oz.*	*lbs.*
409½	*	Aug. 23					
410	Algerian White	July 28	Sept. 15	4.88	0.26		
410½		" 14	" 8	2.9	0.26	8	55
411	Hungarian	Aug. 4	" 15	3.52	0.32	2	41
412	Prize	July 5	" 8	3.8	0.25	14	56.5
413	Little Wonder	" 19	" 8	3.26	0.28	13	55
414	Champion	" 19	" 12	3.65	0.33	13	52
416	Oakshot's Champion	" 12	" 8	3.26	0.3	14	59.5
417	*Incomparable						
418	Fillbag	" 5	Aug. 29	2.6	0.24	17	64
419	McDowell	" 19	Sept. 8	3.58	0.33	9	56.5
420	Young's	" 12	" 8	3.5	0.33	22	57
421	California Red	" 5	" 8	3.0	0.28	11	60.5
422	Little Club	" 19	" 12	3.2	0.2	9	50
423	*Dookie	Aug. 23					
424	Essex	July 19	" 12	3.39	0.35	16	54
425	Purple	" 19	" 8	3.42	0.33	10	54.5
426	Tuscan	" 14	" 8	3.26	0.36	16	58
427	Jubilee	" 12		3.2	0.37	14	63
428	Leake's	" 19	" 8	3.26	0.3	10	59
431	Rodi	" 5	Aug. 29	2.4	0.28	13	65
431½		" 5	Sept. 8	2.61	0.3	11	61
431⅓		" 12	Aug. 31	2.71	0.33	12.5	63.5
432	Dera	" 5	" 29	2.3	0.26	9	63.5
433	Baggi	" 5	" 29	2.3	0.24	10	65.5
434	Ratti	" 5	Sept. 8	2.5	0.3	10	64
435	Dorin	" 5	Aug. 29	2.1	0.29	9	64
436	Pilli	" 5	" 29	2.3	0.3	10	65
437	Walu	" 5	" 29	2.3	0.27	9	63.5
438	*Lohi	" 28					
439	Khel	" 5	" 29	2.6	0.29	10	63.5
b439		" 5	" 29	2.3	0.3		
440	Shega	" 5	" 29	2.3	0.3	11	63
441	Awal No. 1	" 5	" 29	2.20	0.27	11	63
442	" No. 2	" 5	" 29	2.3	0.27	12	63.5
443	Arizona Indian	" 5	" 29	2.9	0.25	12	64
444	Archer's Prolific	" 12	Sept. 8	3.1	0.37	12	52.5
445	Dattel	Aug. 12	" 20	3.45	0.28	1	43
446	Daub 1	July 12	" 12	4.01	0.32	12	54
447	Farrie's Durum	" 23	" 8	3.67	0.33	9	52.5
448	Barwick	" 23	" 12	3.1	0.3	14	55.5
449	*Early Jasper						
b449		" 14	" 8	3.58	0.28	15	61
449½		" 14	" 8	3.26	0.3	8	55
450	Bancroft	" 12	" 8	3.0	0.23	12	61
451	Toronto	" 12	" 8	2.85	0.35	9	59
452	Banater	" 12	" 12	3.26	0.23	17	65
453	Paros	" 12	" 8	3.26	0.25	18	61.5
454	Cape	" 14	" 12	3.0	0.28	15	51.5
455	Nashi	" 12	" 12	3.33	0.21	12	57
456	Hudson's	" 12	" 12	3.1	0.33	5	50
457	Murray River	" 12	" 8	3.42	0.33	12	58.5
458	Green Mountain	" 12	" 8	3.42	0.4	11	58
459	Stockton	" 12	" 8	3.26	0.26	6	62
460	Cordova	" 14	" 8	3.58	0.35	10	56

*This is a winter variety.

TABLE III (Continued).—*Wheat, 1898.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row	Weiget per bu.
				feet	*feet*	*oz.*	*lbs.*
461	Little Club	July 14	Sept. 8	2.94	0.15	10	56.5
462	Algerian	" 12	" 8	3.5	0.26	17	63
463	Carter's 1	" 19	" 8	3.72	0.33	10	57.5
464	Laird's Prolific	" 19	" 8	3.59	0.38	11	55.5
465	Borneo	" 14	Aug. 31	3.45	0.26	23	61.5
466	Reiti 1	" 23	Sept. 12	4.04	0.37	6	54
467	Veneta	" 23		3.88	0.33	7	49
468	Varlsotta	" 23	" 12	3.35	0.33	11	58.5
469	Noah	" 19	" 8	3.26	0.35	9	57
470	Belolourka	" 12	" 8	3.4	0.21	17	64
471	Reiti 2	" 19	" 12	3.26	0.35	7	53
472	Bordeaux	" 23	" 8	3.59	0.3	12	56
472½		" 19	" 8	3.26	0.36	8	55.5
474	Blood Red	Aug. 4					
475	Herisson	July 19	" 12	3.29	0.16	21	54.5
476	White Flanders	Aug. 12	" 15	3.52	0.36		
477	*Australian	" 12					
478	Fleck	July 19	" 8	3.4	0.39	12	59
478½		" 23	" 12	3.43	0.33	9	54
479		" 19	" 12	3.1	0.15	11	53.5
480		" 14	" 12	3.06	0.17	10	56.5
481		" 14	" 12	3.52	0.35	9	51
482		" 12	" 8	3.51	0.37	10	59
483		" 12	" 8	3.26		8	60
484		" 14	" 8	3.59	0.4	8	59
485		" 12	" 8	3.0		7	54
486		" 19	" 8	3.26	0.3	8	59.5
487		" 12	" 8	3.26		9	60
488		" 14				10	60.5
489		" 19	" 8			7	56
490		" 19	" 12	2.64	0.23	4	52
491		" 12	" 8			9	58.5
492		" 19	" 8	3.26	0.3	9	56.5
493		" 19	" 8	3.0	0.41	5	55
494		" 19	" 8	3.50		10	58
495		" 14	" 8	3.0		8	57
496		" 19	" 8	3.5		10	57.5
497		" 19	" 8	3.3		10	60.5
499		" 12	" 8	2.94	0.28	1	52
499½		" 19	" 8	3.26	0.3	9	57
500		" 12	" 8	3.26		10	60
502		" 19	" 8	3.59	0.39	10	57
503		" 12	" 8	3.5		9	58
504		" 19	" 8	3.56		15	60
505		" 12	" 8	3.0		16	60
506		" 12	" 8	3.26		15	59
507	*	Aug. 23					
508	*	" 27					
509	*	" 17					
510		July 28	" 12	3.55	0.39		
511	*	Aug. 12					
512	*	" 12					
513	*	" 27					
514	*	" 30					
515	*	" 23					

*This is a winter variety.

TABLE III (Concluded).—*Wheat, 1898.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row	Weight per bu.
				feet	*feet*	*oz.*	*lbs.*
516	. . . .	Aug. 12	Sept. 15	3.1	0.31	1	49
517	*	" 4					
518	*	" 30					
519	*	" 23					
520	*	" 23					
521	*	" 23					
522	. . . .	" 4	" 20	3.85	0.35	2	58
523	*	" 27					
524	. . . .	" 12	" 20	3.85	0.41	1	36
525	*	" 23					
526	*	" 17					
527	*	" 27					
528	*	" 23					
533	*	" 27					
533½	*	" 27					
534	*	" 23					
*b*534	*	" 23					
535	*	" 30					
536	*	" 23					
537	. . . .	" 17	" 15	3.39	0.35	4	52
538	*	" 30					
539	*	" 30					
540	. . . .	" 19	" 12	3.0	0.3	6	53
541	. . . .	" 4	" 15	3.2	0.26	1	47.5
542	. . . .	" 4	" 15	3.2	0.26	2	47.5
543	. . . .	" 4	" 15	3.2	0.26	1	41.5
544	*	" 4					
545	. . . .	July 12	" 12	2.75	0.32	9	62.5

*This is a winter variety.

TABLE IV.—*Wheat, 1899.*

This gives the results of the second year's trial of all the varieties reported in Table III which matured seed in 1898. One row 10 feet long of each variety was planted. The rows were 20 inches apart.

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row
				feet	*feet*	*oz.*
1	Minnesota Fife.	July 28	Sept. 8	2.8	0.33	7
2	White Fife.		" 8	3.26	0.33	3
3	Sherman	" 20	" 8	2.8	0.28	6
4	White Russian.	" 24	" 8	2.8	0.28	6
5	Odessa.		" 16	2.9	0.35	2.5
6	*Eldorado					
7	Soft Australian.	" 28	" 16	3.0	0.3	4.5
8	Defiance	" 28	" 16	3.0	0.3	3
9	Champion	" 28	" 16	2.9	0.35	5
10	Oregon Club.	" 28	" 16	3.0	0.25	3
11	Hard Australian	" 28	" 16	3.5	0.33	7
12	Sonora	" 14	" 16	2.5	0.23	3
13	White Mexican.	" 24	" 8	3.26	0.28	10
14	Improved Fife	" 28	" 8	3.26	0.3	8
16	Brooks.	" 28	" 8	3.6	0.35	9.5
17	Rio Grande	" 20	" 8	3.4	0.35	8
18	Canada Club.	" 24	" 8	3.26	0.25	5.5
19	Judkin.	" 28	" 8	3.4	0.35	9.5
20	Lost Nation	" 24	Aug. 30	3.26	0.33	9
21	Touzelle	" 14	Sept. 8	3.2	0.3	10
22	Australian Club	" 24	" 8	3.26	0.35	14.5
23	Golden Globe		" 16	3.6	0.36	10.5
24	Mediterranean Spring .	" 24	" 8	3.6	0.33	11.5
25	China Tea	" 24	" 8	3.75	0.35	8.5
26	Chili	" 20	" 8	3.26	0.3	16
27	China Spring.	" 24	" 16	3.8	0.35	5
28	Egyptian.	" 28	" 16	3.6	0.23	2.5
29	Saxon Fife		" 16	3.26	0.3	4
30	Dominion	" 28	" 16	3.26	0.3	3
31	Prussian.	" 28	" 8	3.0	0.25	7
32	Golden Drop.	" 28	" 8	3.26	0.3	8
33	Pringle's No 6.	" 24	" 8	3.26	0.3	8
34	" No. 4.	" 28	" 8	4.0	0.3	10.5
35	" No. 5.	" 24	" 8	3.59	0.27	9
36	Winter Australian . . .	" 28	" 16	3.5	0.3	7.5
38	*Fultz					
39	Midge Proof	" 28	" 16	3.5	0.33	7
40	Black Centennial . . .	" 28	" 8	3.6	0.25	10
41	Hedgerow	" 24	" 16	2.8	0.16	7
42	Granite	" 24	" 16	3.0	0.3	6
43	Italian.	" 14	" 8	3.4	0.23	1.5
44	New York Flint	" 24	" 8	3.26	0.3	11
45	Bald Baltic.	" 20	" 8	3.1	0.3	9.5
48	Red Orange	" 24	" 8	3.4	0.4	8
50	Perkey	" 14	" 8	2.9	0.25	12
51	Hybrid No. 10	" 28	" 16	3.6	0.36	4.5
52	Golden Chaff.	" 20	" 8	3.25	0.33	8
53	Med'ranean Red Chaff	" 28	" 16	3.4	0.3	6
54	Velvet Chaff		" 16	3.8	0.33	5
55	Turkey.	" 28	" 16	3.2	0.28	7
56	Sardonyx		" 16	3.6	0.33	5
57	Amethyst		" 16	3.6	0.35	8

*Damaged by gophers.

TABLE IV (Continued).—*Wheat, 1899.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row
				feet	*feet*	*oz.*
58	Ruby		Sept. 16	3.59	0.35	3
59	Jasper	July 24	“ 8	3.8	0.33	8.5
60	Sapphire	“ 20	“ 8	3.26	0.33	7
r60		“ 28	“ 8	4.0	0.38	4.5
61	Chalcedony	“ 28	“ 8	3.7	0.3	11.5
62	Emerald	“ 28	“ 8	3.8	0.4	9
63	Black Chaff	“ 24	“ 16	3.7	0.23	5
b63			“ 16	3.7	0.3	2
64	Cretan	“ 24	“ 16	3.85	0.23	7
65	Andriola Red	“ 24	“ 8	3.4	0.25	12
66	“ Amber	“ 20	“ 8	3.26	0.23	6
67	Purple Chaff	“ 24	“ 8	3.4	0.16	12.5
68	Boughton	“ 28	“ 16	3.26	0.18	10
70	Anautka	“ 20	“ 16	3.9	0.3	11.5
71	Fountain	“ 28	“ 16	3.9	0.33	11
72	Palestine		“ 16	3.75	0.4	7
73	White Chaff (smooth)	“ 24	Aug. 30	3.26	0.25	10.5
76	Perfection	“ 28	Sept. 8	3.5	0.3	8.5
77	German Fife	“ 24	“ 8	3.8	0.35	11
78	Mammoth	“ 28	“ 16	3.7	0.35	5
80	Samara	“ 24	“ 16	3.6	0.2	6
81	Durum	“ 20	“ 16	3.6	0.2	8.5
82	Saratov	“ 24	“ 8	3.5	0.3	10
83	Ames	“ 20	“ 8	4.0	0.23	10
84	Moscow	“ 24	“ 8	3.6	0.3	9
85	Knapp	“ 24	“ 8	3.7	0.25	12
86	Scotch Fife	“ 28	“ 16	4.0	0.3	7
87	Doty	“ 20	Aug. 30	3.5	0.25	11
88	Meekins	“ 20	Sept. 8	3.8	0.33	6
89	White Michigan	“ 29	“ 8	3.5	0.33	8
90	Rickenbrode	“ 29	“ 16	3.55	0.33	5.5
93	Black Beard	“ 20	“ 8	3.7	0.25	9
98	German Amber		“ 16	3.0	0.36	0.5
100	Dallas		“ 16	3.5	0.39	5.5
102	Finlay					
110	Propoe	“ 24	“ 8	3.26	0.3	10
112	Red Clawson					
117	Big May	“ 28	“ 8	3 4	0.33	10.5
118	Sardius	“ 29	“ 8	3.8	0.3	15.5
119	Chrysolite	“ 24	“ 8	3.26	0.33	6.5
120	Beryl	“ 24	“ 8	3.26	0.28	8.5
122	Jacinth	“ 20	Aug. 30	3.26	0.26	12
123	Carnelian	“ 28	Sept. 16	3.5	0.25	10
124	Agate	“ 24	“ 16	3.5	0.25	10.5
125	Onyx	“ 28	“ 16	3.6	0.28	11.5
126	Opal	“ 28	“ 16	3.5	0.26	
127	Garnet	“ 30	“ 16	3.8	0.33	
128	Tourmaline	“ 28	“ 8	3.8	0.15	12
129	Felspar	“ 28	“ 16	3.26	0.28	3
131	Casaca		“ 8	3.75	0.33	7.5
133	Tuscan	“ 29	“ 16	3.5	0.33	
135	Tuskana					
136	Pearl			3.26	0.4	5
138	White Chaff	“ 24	“ 16	3.26	0.25	11.5
145	Red Oregon Club		“ 16	3.26	0.28	13
146	Hedgerow					
147	Aowse	Aug. 25		3.8	0.4	1.5

TABLE IV (Continued).—*Wheat, 1899.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row
				feet	*feet*	*oz.*
357	Steinwedel's Early. . .	July 20	Sept 8	3.2	0.38	9.5
358	Rattling Tom	" 20	" 8	3.26	0.28	10
359*a*	. . . .	" 20	" 16	3.4	0.2	
359*b*	. . . .	" 20	" 16	3.3	0.25	5
360	Missogen.	" 24	" 16	4.0	0.35	6.5
361	Atlanti.	" 24	" 16	3.4	0.25	8
363	Sadoza.	" 24	" 8	3.5	0.28	10.5
364	Curtis' White.	" 24	" 8	3.7	0.35	13.5
365	Seven Headed Red. . .	" 24	" 16	3.95	0.25	6.5
366	Ontario	" 20	" 16	3.1	0.15	8
366½	. . . .	" 20	" 16	3.3	0.2	7
377	Egyptian No. 8.	" 28	" 16	3.65	0.35	10
383	" F	" 20	" 16	3.5	0.3	7
388	Carter's A	" 29	" 16	3.65	0.3	
389	" B					
393	" F	Sept 15				
307	" J	Aug. 5	" 16	3.6	0.25	2.5
398	" L	Sept. 8				
398½	. . . .					
400	Algerian No. 1.	Jnly 20	" 8	3.26	0.2	12.5
401	" No. 2.	" 20	" 8	3.26	0.2	18
401½	. . . .	" 20	" 8	3.26	0.28	15.5
*b*402	. . . .	" 20	" 8	3.26	0.25	10.5
402½	. . . .	Aug. 20				
404	Galland Hybrid	" 5	" 16	3.8	0.25	3
405	Zeland	" 5	" 16	3.4	0.36	4
406	Lanneurde Mars	" 5	" 16	3.0	0.35	5
407	Berthoud	Sept. 1				
408	Mold's White	" 16				
409	" Red.	Aug. 5	" 16	3.1	0.36	7.5
410½	. . . .	July 24	" 16	2.5	0.3	7
411	Hungarian	Aug. 5				
412	Prize.	July 20	" 8	3.7	0.23	16
413	Little Wonder	" 28	" 8	3.5	0.28	11 5
414	Champion	" 24	" 8	3.5	0.25	14.5
416	Oakshot's Champion. . .	" 20	" 8	3.59	0.26	14.5
418	Fillbag.	" 14	Aug. 30	2.8	0.2	10
419	McDowell	" 24	Sept. 8	3.45	0.26	11
420	Young's	" 20	" 8	3.85	0.25	9
421	California Red.	" 14	" 8	3. 1	0.26	6.5
422	Little Club	" 24	" 16	2. 8	0.15	
424	Essex	" 24	" 8	3. 5	0.25	8
425	Purple.	" 24	" 8	3.59	0.25	10.5
426	Tuscan.	" 24	" 8	3.35	0.25	9
427	Jubilee	" 14	" 8	3.26	0.3	13
428	Leake's	" 24	" 8	3.4	0.26	10
431	Rodi.	" 14	Aug. 30	2.7	0.25	11.5
431½	. . . .	" 14	Sept. 8	2.8	0.23	14
431⅓	. . . .	" 14	" 8	2.8	0.26	10
432	Dera.	" 14	" 8	2.8	0.25	12.5
433	Baggi	" 14	Aug 30	2.7	0.23	11
434	Ratti	" 14	Sept. 8	2.93	0.25	10
435	Dorin	" 14	" 8	2.5	0.23	14
436	Pilli	" 14	" 8	2.5	0.3	13.5
437	Walu	" 14	" 8	2.61	0.23	4.5
438	Lohi.	" 14	" 16	3.15	0.2	
439	Khel.	" 14	Aug. 30	2.0	0.25	7.5

TABLE IV (Continued).—*Wheat, 1899.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row
				feet	*feet*	*oz.*
439		July 14	Aug. 30	2.8	0.25	8.5
440	Shega	" 14	" 30	2.8	0.23	10.5
441	Awal No. 1	" 14	Sept. 8	2.65	0.2	5
442	" No. 2	" 14	" 8	2.4	0.23	6.5
443	Arizona Indian	" 14	Aug. 30	3.0	0.21	13
444	Archer's Prolific	Aug. 5	Sept. 16	3.7	0.25	11
445	Dattel					
446	Daub I	July 20	" 16	4.1	0.25	12.5
447	Farrie's Durum	" 28	" 16	3.6	0.3	7
448	Barwick	" 28	" 16	3.75	0.3	6.5
449	Early Jasper	" 20	" 8	4.0	0.2	
449½		" 28	" 16	3.65	0.2	12
450	Bancroft	" 14	" 8	2.85	0.2	4.5
451	Toronto	July 20	Sept. 8	3.26	0.3	10.5
452	Banater	" 24	" 16	3.8	0.24	9.5
453	Paros	" 24	" 16	3.8	0.22	12
454	Cape	" 20	" 8	3.26	0.25	15.5
455	Nashi	" 20	" 8	3.4	0.18	6
456	Hudson's	" 20	Aug. 30	3.1	0.21	16
457	Murray River	" 24	Sept. 8	3.1	0.25	10
458	Green Mountain	" 20	" 8	3.5	0.33	10
460	Cordova	" 24	" 8	3.5	0.33	8.5
461	Little Club	" 24	" 16	3.0	0.18	9.5
462	Algerian	" 20	" 8	3.45	0.23	14
463	Carter's I	Aug. 5	" 16	3.8	0.25	6
464	Laird's Prolific	July 24	" 8	3.6	0.35	12
465	Borneo	" 20	Aug. 30	3.2	0.23	15.5
466	Reiti 1	Aug. 20				
467	Veneta	" 20				
468	Varlsotta	" 20				
469	Noah	July 29	Sept. 8	3.8	0.3	4.5
470	Belolourka	" 20	" 8	4.0	0.21	12.5
471	Reiti 2	Aug. 20				
472	Bordeaux	" 5	" 16	4.0	0.25	7
472½		" 5	" 16	3.7	0.3	12.5
475	Herisson	July 28	" 8	3.8	0.15	9
478	Fleck	" 28	" 8	3.5	0.35	10
478½		Aug. 20				
479		July 28	" 16	3.45	0.15	12.5
480		" 28	" 16	3.4	0.15	4.0
481		" 28	" 16	3.25	0.3	6.5
482		" 24	" 8	3.8	0.35	6
483		" 28	" 16	3.6	0.3	11
484		" 28	" 16	3.7	0.35	6
485		" 20	" 8	3.5		12.5
486		" 28	" 8	3.5	0.25	10
487		" 20	" 8	3.55		7
488		" 24	" 8	3.8		9
489		" 20	" 8	3.59	0.25	10
490		" 20	" 8	3.59	0.26	7.5
491		" 20	" 8	3.59	0.3	12
492		" 24	" 16	3.5	0.35	7
493		" 28	" 8	3.91	0.35	9
494		" 28	" 8	3.75	0.4	9.5
495		" 20	" 8	3.59	0.35	11
496		" 20	" 8	3.55	0.33	9
497		" 24	" 8	3.4	0.28	13

TABLE IV (Continued).—*Wheat, 1897.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row
				feet	*feet*	*oz.*
490	....	July 20	Aug. 30	3.26	0.23	16.5
490½	....	" 24	Sept. 8	3.4	0.25	9.5
500	....	" 20	Aug. 30	3.1		14.5
501	....	" 28	Sept. 16	3.65	0.35	5
502	....	" 28	" 16	3.55	0.3	8
503	.. ..	" 28	" 16	3.65	0.2	8.5
504	....	" 24	" 8	3.6	0.33	10.5
505	....	" 20	" 8	3.65	0.28	12.5
506	....	" 20	" 8	3.26	0.25	7
516	....	Sept. 10				
517	....	" 10				
522	....	" 15				
524	....					
537	... .	" 1				
540	....	July 28	" 16	3.53	0.35	12.5
541	. ...	Sept. 15				
542	....	" 15				
543	....	" 15				
544	....	" 1				
545	....	July 20	" 8	2.35	0.25	13

TABLE V.—*Oats, 1896.*

This gives the results of oats grown from seed furnished by Professor Vestal of New Mexico during the season of 1896. One row 50 feet long of each variety was planted. The rows were 18 inches apart.

No.	NAME	Date headed		Date ripe		Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row		Weight per bu.
						feet	*feet*	*lbs.*	*oz.*	*lbs.*	*oz.*	*lbs.*
2	Board of Trade	July	13	Sept.	4	3.8	0.9	12	10	4	11	42
3	Australian	"	17	"	4	3.6	0.85	11	4	4	6	45
5	Pringle's Hulless	"	13	"	17	3.7	0.9	8	13	2	11	46.5
6	" No. 6	"	23	Oct.	7	4.0	0.8	9	2	2	12	38
7	" No. 4	"	25	"	7	3.85	0.8	8	9	2	14	38
8	" No. 6	"	23	Sept.	17	4.0	1.0					40
9	Belgio-Russian	"	25	"	17	4.1	0.8	7	3	2	8	37
11	Russian Black	"	23	"	17	4.0	0.7	8	12	3	4	40
13	New Zealand	"	13	"	4	3.8	0.95	11	2	4	2	43
14	White Russian	"	23	Oct.	7	4.2	0.9	10	14	1	13	39
15	Black Tartarian	"	31			4.0	0.9	9	3	1	12	31
16	Early Yellow	"	31	"	7	3.9	1.35	8	9	1	12	39
17	Early Poland	"	13	Sept.	4	3.2	0.7	10	13	4	5	43
18	Poland	"	27	Oct.	7	3.6	0.95	8	4	1	7	38
19	Potato	"	31	"	7	4.0	0.85	7	12		12	36
21	Chinese Hulless	"	23	Sept.	17	4.3	1.0	12		2	14	47
23	Pringle's Excelsior	"	11	"	17	3.7	0.9	9	4	2	11	50
24	Rust Proof	"	17	Aug.	31	2.6	0.4	7	15	3		35
28	South Carolina Black	"	13	Sept.	8	3.9	0.7	14	14	5	10	39
31	Clydesdale	"	23	"	8	4.6	1.0	14	3	4	10	44
32	Colorado Yellow	"	20	"	17	3.8	0.95	11	8	3	4	41
34	Austrian No. 2	"	13	"	8	4.0	1.0	10	4	4	14	45
35	American Beauty	"	17	"	4	3.6	0.9	9	9	3	11	41
39	Black Champion	"	23	"	17	3.45	0.75	3	14	3	3	36
40	Monarch	Aug.	8	Oct.	7	4.15	0.7	10	4		9	32
42	Race Horse	July	17	Sept.	17	2.5	1.0	7	5	2	3	45
44	Swiss Black	Aug.	3	Oct.	5	4.0	0.65	11	3	2	5	40
45	Victoria	July	17	Sept.	4	3.5	0.7	8	14	3	1	
46	Hopetown	"	23	"	17	3.6	0.7	10		4	6	40
47	Waterloo	"	31	"	17	4.0	0.85	11	11	4	10	38
49	Silesian	"	20	"	2	3.9	0.9	10	4	3	9	42
50	Golden Giant	"	31	"	31	4.6	1.2	9	7	1	9	35
51	Orient	"	31	Oct.	7	4.0	1.25	10	6	1	11	41
52	Lost	"	31	"	5	4.2	1.35	10	4	1	11	37
53	Improved American	"	25	Sept.	17	4.1	0.8	10	11	3	8	38
54	Hargett's White	"	20	"	8	3.4	0.9	12	3	4	8	43
55	Excelsior	"	25	"	17	4.0	0.75	14	10	4	14	40
56	Highbred	"	13	"	2	3.8	0.85	9	14	3	11	45
59	Cape	June	29	Aug.	15	1.5	0.35	4	4	1	8.5	40
66	Algerian	July	6	Sept.	4	2.8	0.45	6	5	2	6	

TABLE VI.—*Oats, 1897.*

This gives the results of the second year's trial of all the varieties reported in Table V. One row 50 feet long of each variety was planted. The rows were 18 inches apart.

No.	NAME	Date headed		Date ripe		Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row		Weight per bu.
						feet	*feet*	*lbs.*	*oz.*	*lbs.*	*oz.*	*lbs*
1	White Dutch	July	20	Sept.	8	3.5	0.7	9	12	2	8.5	40
2	Board of Trade	"	22	"	3			8		2	0.5	43
3	Australian	"	22	"	11	4.1	0.85	8	10	2	4	39
5	Pringle's Hulless	"	20	"	4	3.35	0.93	7	12	2	1	43.5
6	" No. 6	"	22	"	11	3.65	0.88	10	6	2	14	40
7	" No. 4	"	26	"	11	3.67	0.75	9	13	2	12	38
8	" No. 6	"	28	"	22	3.87	0.78	10	11	2	13	37
9	Belgio-Russian	"	26	"	8	3.33	0.72	7	2	2	12	31.5
11	Russian Black	"	26	"	22	3.34	0.92	12	4	2	9	
13	New Zealand	"	28	"	22	3.66	1.11	9	5	2	12.5	36
14	White Russian	"	28	"	23	4.3	0.86	19	1	2	2	38
15	Black Tartarian	"	28	"	8	3.6	0.65	7	8	1	1	
16	Early Yellow	"	31	"	11	3.89	0.79	11	1	3	2.5	36
17	Early Poland	"	26	"	11	3.74	0.92	6	11	2	6	40.5
18	Poland	"	28	"	13	3.63	0.84	10		2	8	33
19	Potato	Aug.	9	"	22	3.33	0.93	7	3	2	8	36
21	Chinese Hulless	July	26	"	3			8	13	2	6	48
23	Pringle's Excelsior	"	20	"	4	3.68	0.77	7	2	1	10	48
24	Rust Proof	"	26	"	11	3.26	0.45	8	8	2	2	
28	South Carolina Black	"	20	"	22	3.8	0.75	11	13	3	1	34.5
31	Clydesdale	"	26	"	3	3.53	0.88	7	10	2	3	47
32	Colorado Yellow	Aug.	9	"	22	3.75	0.85	12	3	2	12	36
34	Austrian No. 2	July	22	"	11	3.92	0.8	8	12	2	11	40
35	American Beauty	"	22	"	11	3.8	0.85	9	2	3	0.5	39.5
39	Black Champion	"	26	"	11	3.27	0.6	7		2	7	39
40	Monarch	"	28	"	22	3.87	0.81	9	1	2	6	38
42	Race Horse	"	26	"	11	3.69	0.72	9	1	2	6	41
44	Swiss Black	"	20	"	22	4.0	0.7	13	2	3	14	38
45	Victoria	"	20	"	8	4.0	0.85	9	10	3	4	41.5
46	Hopetown	"	26	"	8	3.74	0.73	8	13	2	13	38
47	Waterloo	"	20	"	22	3.6	0.55	13	15	3	12	38.5
49	Silesian	"	20	"	22	3.7	0.65	12	11	3	9	42
50	Golden Giant			"	22	3.52	0.85	6	9	1	15	35.5
51	Orient	"	28	"	11	3.7	0.7	8	4	1	6	
52	Lost	"	26	"	22	3.48	0.74	10	6	2	5	40
53	Improved American	"	26	"	8	3.99	0.82	10	8	3	3.5	40.5
54	Hargett's White	"	20	Aug.	30	3.36	0.72	5	13	1	13	41
55	Excelsior	"	26	Sept.	8	3.91	0.68	8	4	2	15	
56	Highbred	"	20	"	3	3.77	0.75	9	14	4	4	42
59	Cape	"	8	Aug.	25	2.2	0.32	3	14	1	11	32
66	Algerian	"	28	Oct.	7	3.5	0.6	4	6	1	1	35

TABLE VII.—*Oats, 1898.*

This gives the results of the first year's trial of Professor Blount's collection of oats. The varieties reported on in Tables V and VI were originally from Professor Blount, but the varieties reported in the following table were grown from seed selected by him personally and furnished gratis to the Station. One row ten feet long of each variety was planted. The rows were 20 inches apart

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row	Weight per bu.
				feet	*feet*	*oz.*	*lbs.*
1	White Dutch	July 12	Aug. 15	3.29	1.03	6	39.5
2	Board of Trade	" 12	" 15	3.3	0.94	8	38.5
3	Australian	" 19	" 15	3.29	0.88	7.5	38
4	Black American	" 14	" 23	3.03	0.67	9	32.5
5	Pringle's Hulless	" 19	" 19	3.0	0.68	4.5	40
6	" No. 6	" 23	" 27	3.31	0.63	13.5	35.5
7	" No. 4	" 23	Sept. 2	3.65	0.82	10.5	36
8	" No. 6	" 23	" 9	4.24	1.08	6	35.5
9	Belgio-Russian	" 23	Aug. 27	3.29	0.84	13	37
10	Schoenon	" 23	" 27	3.1	0.81	5	37
11	Russian Black	" 19	" 27	3.3	0.75	13	37
12	Alexander	" 19	" 29	3.28	0.75	15	38
13	New Zealand	" 14	" 15	3.21	0.88	9	38.5
14	White Russian	" 23	Sept. 6	3.68	0.98	3	37.5
15	Black Tartarian	" 23	Aug. 31	3.03	0.73	10	34.5
16	Early Yellow		Sept. 6	3.22	0.82	11.5	36.5
17	Early Poland	" 19	Aug. 15	3.28	0.88	6	36
18	Poland	" 18	Sept. 6	3.55	0.7		35
20	Early Angus	" 23	Aug. 31	3.72	0.95	11	35.5
21	Chinese Hulless	" 19	" 23	3.3	0.78	4.5	47
22	Triumph	" 28	Sept. 6	4.04	0.78	8.5	35
23	Pringle's Excelsior	" 12	Aug. 19	3.27	0.72	5	40.5
24	Rust Proof	" 5	" 15	2.82	0.49	11.5	37
25	White Eureka	" 19	" 27	3.27	0.72	17	38
26	Welcome	" 19	" 16	3.31	0.88	7.5	41
27	Novelty	" 23	Sept. 6	3.55	0.88	8	34.5
28	South Carolina Black	" 5	Aug. 15	3.05	0.63	10.5	36
29	Golden Sheaf	" 19	" 27	3.31	0.85	16.5	39.5
30	Probster	" 19	" 29	3.3	0.8	15	39
31	Clydesdale	" 12	" 15	3.31	0.79	9.5	41.5
32	Colorado Yellow	" 19	Sept. 6	4.04	0.73	14	37.5
33	Austrian No. 1	" 19	Aug. 31	4.27	0.72	19	38.5
34	" No. 2	" 12	" 17	3.31	0.9	13	41.5
35	American Beauty	" 14	" 19	3.28	0.86	13	39
36	Burpee's Welcome	" 19	" 23	3.31	0.91	7	41.5
37	Bohemian	" 19	" 27	3.32	0.91	9	40
38a		" 19	" 27	4.0	0.76	20	37
38b		" 23	" 27	3.31	0.85	13.5	38
39	Black Champion	" 23	" 29	3.67	0.76	15	33.5
40	Monarch	" 23	" 12	4.5	0.92	5	37
41	Dakota	" 19	" 23	4.0	0.75	12	39.5
42	Race Horse	" 19	Sept. 2	4.03	0.88	14	38
43	Canadian	" 19	Aug. 29	4.07	0.82	17	30
44	Swiss Black	" 28	Sept 12	4.01	0.84	12	36
45	Victoria	" 14	Aug. 16	3.58	0.72	12	38
46	Hopetown	" 23	" 29	4.08	0.72	14	37
47	Waterloo	" 19	" 27	3 65	0.77	13.5	36.5
48	Harris	June 30	" 15	2.57	0.54	6.5	29
49	Silesian	July 19	" 16	3.75	0.88	8	36
50	Golden Giant	" 28	Sept. 12	3.97	1.12	5	35
51	Orient	" 28	" 6	4.24	0.95	10.5	37
52	Lost	" 28	" 6	3.75	0.75	11	34.5

TABLE VII (Continued).—*Oats, 1898.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row	Weight per bu.
				feet	*feet*	*oz.*	*lbs.*
53	Improved American	July 23	Aug. 27	3.88	0.77	16	36.5
54	Hargett's White	" 19	" 16	3.75	0.92	10.5	40
55	Excelsior	" 14	" 16	3.65	0.92	7	37
56	Highbred	" 15	" 16	3.55	0.94	8.5	38
57	Algerian No. 1	" 12	" 27	3.75	0.82	15	39
58	" No. 2	" 5	" 16	3.11	0.72	7	31
59	Cape	June 30	" 16	2.44	0.43	3	30
62	Tasmanian	July 23	Sept. 6	4.14	0.96	10	35
63	Foxtail	" 14	Aug. 16	3.75	0.68	9	37.5
65	Farrer	" 5	" 16	3.1	0.37	7.5	33.5
66	Algerian	" 5	" 16	3.25	0.57	8	31.5
68			" 16	3.04	0.65	5.5	27.5
69		" 19	" 29	3.33	0.63	15	34.5
71		" 19	" 31	3.44	0.75	16	37
72		" 12	" 29	4.31	0.9	4	20
73		" 19	" 29	3.98	0.73	19	37.5
74		" 19	Sept. 2	3.85	0.81	17.5	37.5
75		" 19	" 2	4.17	0.39	16	38.5
76		" 23	" 2	4.5	0.91	16	38
77		" 23	" 2	4.75	0.78	12	39
78		" 23	" 2	4.44	0.85	7.5	33

TABLE VIII.—*Oats, 1899.*

This gives the results of the second year's trial of all the varieties reported in Table VII. One row 10 feet long of each variety was planted. The rows were 20 inches apart.

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row
				feet	*feet*	*oz.*
1	White Dutch	July 28	Sept. 8	2.8	0.85	6
2	Board of Trade	" 24	" 8	2.5	0.62	6.5
3	Australian	" 24	" 8	2.85	0.8	6
4	Black American	" 24	" 8	2.8	0.7	10
5	Pringle's Hulless	" 20	Aug. 20	2.7	0.6	8
6	" No. 6	" 20	Sept. 8	3.0	0.6	11.5
7	" No. 4	" 24	" 8	3.0	0.6	10.5
8	" No. 6	" 24	" 8	3.28	0.8	11.5
9	Belgio-Russian	" 24	" 8	3.25	0.7	12
10	Schoenon	" 24	" 8	3.28	0.7	12.5
11	Russian Black	" 20	Aug. 30	3.2	0.7	11
12	Alexander	" 20	Sept. 8	3.4	0.6	17.5
13	New Zealand	" 20	Aug. 28	3.1	0.8	10
14	White Russian	" 28	Sept. 8	3.5	0.8	15.5
15	Black Tartarian	" 28	" 8	3.0	0.65	12
16	Early Yellow		" 8	3.0	0.8	14

TBBLE VIII (Continued).—*Oats, 1899.*

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row
				feet	*feet*	*oz.*
17	Early Poland	July 24	Sept. 8	3.26	0.7	10
18	Poland		" 8	3.26	0.65	12.5
20	Early Angus		" 8	3.26	0.75	12
21	Chinese Hulless	" 20	Aug. 22	3.0	0.65	5
22	Triumph		Sept. 16	3.5	0.9	8
23	Pringle's Excelsior	" 20	Aug. 22	3.1	0.6	3.5
24	Rust Proof	" 24	Sept. 8	3.5	0.75	12
25	White Eureka	" 24				15
26	Welcome	" 24	" 8	3.26	0.9	13.5
27	Novelty	" 24	" 8	3.0	0.45	11
28	South Carolina Black	" 20	Aug. 28	3.0	0.6	15
29	Golden Sheaf	" 20	" 27	3.2	0.6	9.5
30	Probster	" 24	Sept. 8	3.5	0.6	18
31	Clydesdale	" 24	" 8	3.59	0.75	10
32	Colorado Yellow	" 20	" 8	3.26	0.6	15
33	Austrian No. 1	" 20	" 8	3.26	0.65	17
34	" No. 2	" 20	" 8	3.26	0.7	15.5
35	American Beauty	" 24	" 8	3.0	0.8	12
36	Burpee's Welcome	" 24	" 8	3.0	0.7	9
37	Bohemian	" 20	Aug. 28	3.1	0.8	10
38a		" 20	" 30	3.0	0.6	12.5
38b		" 28	Sept. 8	3.0	0.65	13
39	Black Champion	" 24	" 8	3.0	0.65	10
40	Monarch		" 16	3.26	1.0	7
41	Dakota	" 28	" 8	3.6	0.8	10.5
42	Race Horse	" 24	" 8	3.26	0.65	14.5
43	Canadian	" 22	" 8	3.4	0.7	18
44	Swiss Black		" 16	3.5	0.9	6
45	Victoria	" 24	" 8	3.5	0.9	14
46	Hopetown	" 24	" 8	3.2	0.6	17
47	Waterloo	" 20	" 8	3.0	0.65	15
48	Harris	" 14	" 8	2.9		4
49	Silesian	" 20	" 8	3.0	0.7	13.5
50	Golden Giant		" 16	3.4	0.8	11
51	Orient	" 28	" 8	3.59	0.7	14
52	Lost		" 8	3.0	0.7	15
53	Improved American	" 24	" 8	3.26	0.65	21
54	Hargett's White	" 24	" 8	3.1	0.85	11
55	Excelsior	" 24	" 8	3.26	0.7	13.5
56	Highbred	" 20	" 8	3.0	0.7	16
57	Algerian No. 1	" 24	Aug. 30	3.1	0.8	22
58	" No. 2	" 16	" 30	2.5	0.4	19
59	Cape	" 14	" 28	2.3	0.35	7
62	Tasmanian	" 28	Sept. 16	3.5	0.7	10.5
63	Foxtail	" 20	" 8	3.1	0.7	12
65	Farrar	" 14	" 8	2.4	0.55	20
66	Algerian	" 28	Aug. 16	3.0	0.55	6
68		" 20	Sept. 8	3.0	0.6	16.5
69		" 28	" 8	3.0	0.65	18
71			" 16	3.5	0.7	10
72		" 28	" 8	3.59	0.8	13
73		" 24	" 8	3.45	0.7	19.5
74		" 20	" 8	3.26	0.55	23.5
75		" 20	Aug. 28	3.2	0.6	20
76		" 24	Sept. 8	3.5	0.65	16
77		" 24	" 8	3.26	0.65	18
78		" 24	" 8	3.26	0.65	23

TABLE IX.—*Barley, 1896.*

This gives the results of barley grown from seed furnished by Professor Vestal of New Mexico, during the season of 1896. One row 50 feet long of each variety was planted. The rows were 18 inches apart.

No.	NAME	Date headed		Date ripe		Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row		Weight per bu.
						feet	*feet*	*lbs.*	*oz.*	*lbs.*	*oz.*	*lbs.*
1	*Smooth Hulless	July	11	Aug.	17	2.2	0.26	9	9	3	2	64
2	Winnipeg No. 1	“	6	Sept.	7	2.5	0.28	10	8	4	2	58
4	*New Zealand	“	17	“	7	3.7	0.4	12	11	5	4	54.5
5	Chevalier	“	25	“	7	3.45	0.4	14	14	4	12	52
7	*Winter (6-rowed)	“	11	“	5	2.61	0.15	13	7	6	10	46
8	Purple	“	6	Aug	25	2.5	0.16	12	1	5	7	58
9	Melon	“	11	“	31	3.4	0.25	15	3	5	15	52
10	Del Norte	“	9	“	27	2.8	0.23	8		3	2	62
11	Triumph	“	20	Sept.	7	3.65	0.35	8	6	4	6	48
13	Kilma	“	11	Aug.	27	2.7	0.325	13	1	5	9	53
14	Scotch Annat	“	11	Sept.	5	3.26	0.4	12	1	4	5	52
15	Black	“	11	Aug.	25	2.7	0.26	11	6	5	1	51
16	Palestine	“	20	Sept.	7	3.35	0.35	9	15	3	10	52
17	Animate	“	25	“	7	3.6	0.4	14	3	4	12	51
18	Guymalye	“	6	Aug.	24	2.5	0.23	6	11	3	8	55
19	Manchurian	“	25	Sept.	7	3.4	0.45					
20	Frick's	“	11	“	5	3.0	0.32	14		5	13	53
21	**Spring (4-rowed)	“	13	“	7	3.0	0.3	**				50
22	Eufurt	“	23	“	7	3.2	0.4	14	6	4	14	54
23	Nepaul	“	11	Aug.	29	3.2	0.33	11	9	4	7	63.5
24	Winter (4-rowed)	“	11	“	27	3.26	0.3	11	8	4	10	48
26	Sibley's Improved	“	17	Sept.	7	3.4	0.3	11	1	4	6	46
27	Mansury	“	11	Aug.	27	3.1	0.33	12	11	5	8	
28	Adams' Heavy	“	11	“	24	3.1	0.3	14	12	6	7	51
29	Sibley's Pearl	“	11	“	24	3.3	0.33					51
32	Berkley	“	11	“	24	3.5	0.32	9	10	3	5	50
33	Zeochrit	“	11	“	31	3.26	0.29	14	5	5	5	53
34	Perigerste	“	23	Sept.	7	3.5	0.4	14	6	5	7	53
40	Algerian No. 2	“	6	Aug.	31	2.7	0.24	10	4	6	10	47
41	“ No. 3	“	6	“	31	2.3	0.22	10	14	5		49
42	Battledore	“	23	Sept.	7	3.4	0.4	15	12	5	8	52.5
46	Himalaya	“	6	“	7	2.5	0.2	9	9	4	12	64½
47	Carter's Prize	“	23	“	7	3.6	0.4	17	2	4	10	52
48	Goldthorpe	“	23	“	7	3.4	0.27	14	6	4	15	

*Seed not obtained from the New Mexico Station.

**Misnamed, as it is a 6-rowed variety. Part of crop lost.

TABLE X.—*Barley, 1897.*

This gives the results of the second year's trial of all the varieties given in Table IX. One row 50 feet long of each variety was planted. The rows were 18 inches apart.

No.	NAME	Date headed		Date ripe		Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row		Weight per bu.
						feet	*feet*	*lbs.*	*oz.*	*lbs.*	*oz.*	*lbs.*
1	Smooth Hulless	July	20	Sept.	7	2.6	0.275	8	12	2	2	63
2	Winnipeg No. 1	"	10	"	7	2.38	0.35	10	12	4	5	61.5
4	New Zealand	"	26	"	3	2.75	0.3	11	2	3	0.5	55.5
5	Chevalier	"	20	"	7	2.4	0.3	9	5	4	1.5	52.5
7	Winter (6-rowed)	"	26	"	11	2.5	0.15	8	13	3	8	47.5
8	Purple	"	10	"	3	2.4	0.18	7	5	2	15	65
9	Melon	"	20	Aug	30	2.96	0.26	10	11	3	7	51
10	Del Norte	"	20	Sept.	7	2.2	0.2	4	14	1	7	62.5
11	Triumph	"	20	"	7	3.0	0.28	13	15	4	10	49.5
13	Kilma	"	13	"	7	2.3	0.22	9	3	3	2	55.5
14	Scotch Annat	"	20	"	7	2.55	0.37	10	6	2	14	53
15	Black	"	20	"	7	2.49	0.31	6	2	1	8	52.5
16	Palestine	"	26	"	7	2.65	0.3	9	8	2	11	55
17	Animate			"	7	2.6	0.3	8	9	2	12	52.5
18	Guymalye	"	16	"	7	2.0	0.275	6	9	2	6	64
19	Manchurian	"	22	"	11	3.11	0.38	18	11	5		54
20	Frick's	"	22	"	7	2.9	0.28	8	13	2	15	54
21	Spring (4-rowed)	"	22	"	7	2.85	0.25	11	13	3	14	49
22	Eufurt	"	26	"	7	2.9	0.4	17	8	3	15.5	55
23	Nepaul	"	10	Aug.	30	2.23	0.26	7		2	6	65
24	Winter (4-rowed)	"	13	Sept.	7	3.0	0.28	8	2	2	3	47
26	Sibley's Improved	"	20	"	3	2.85	0.26	10	2	3	5	46.5
27	Mansury			"	1	3.16	0.34					
28	Adams' Heavy			Aug.	30	2.5	0.28	10	6	1	2	52.5
29	Sibley's Pearl	"	20	Sept.	3	2.9	0.28	7	8	2	10	46.5
32	Berkley	"	20	"	7	2.65	0.27	5	4	1	12	52.5
33	Zeochrit	"	20	"	7	3.22	0.25	10	14	3	14	55
34	Perigerste	"	26	"	7	2.58	0.3	9	6	2	8	55
40	Algerian No. 2	"	26	"	3	2.7	0.25	11	2	2	10	48
41	" No. 3	"	20	"	7	2.5	0.12	6	14	2	9	47.5
42	Battledore	"	22	"	7	2.77	0.36	10	15	3	5	55.5
46	Himalaya	"	10	"	7	2.2	0.2	5	6	2	6	65
47	Carter's Prize	"	22	"	7	2.6	0.3	9	10	2	4	55
48	Goldthorpe	"	26	"	11	2.6	0.4	11	7	3	4	54.5

TABLE XI.—*Barley, 1898.*

This gives the results of the first year's trial of Professor Blount's collection of barleys. The varieties reported on in Tables IX and X were originally from Professor Blount, but the varieties reported on in the following table were grown from seed selected by him personally and furnished gratis to the Station. One row 10 feet long of each variety was planted. The rows were 20 inches apart.

No.	NAME	Date headed	Date ripe	Height	Length of heads	Yield of grain from 10 feet of row		Weight per bu.
				feet	*feet*	*lbs.*	*oz.*	*lbs.*
1	Smooth Hulless	July 5	Aug. 17	2.43	0.3		11	65
2	Winnipeg No. 1	“ 2	“ 17	2.35	0.36		10	65
3	“ No 2	“ 5	“ 16	2.78	0.34		14	50.5
4	New Zealand	“ 12	“ 23	2.58	0.29		12	52
5	Chevalier	“ 19	“ 31	2.45			8	51
6	Zealand	“ 19	“ 23	2.42	0.35			49.5
7	Winter (6-rowed)	“ 23	“ 31	1.96	0.2		12	48
8	Purple	“ 5	“ 17	2.38	0.28			
9	Melon	“ 12	“ 17	2.69	0.28		12	50.5
10	Del Norte	“ 12	“ 17	2.71	0.28	1		64.5
11	Triumph	“ 12	“ 17	2.59	0 27		12	47.5
12	Indian No. 4	“ 12	“ 11	2.79	0.34	1	3	48
13	Kilma	“ 12	“ 23	2.71	0.39	1	8	53
14	Scotch Annat	“ 12	“ 23	2.48	0.37		12	50
15	Black	“ 12	“ 17	2.48	0.26	1	3	47.5
16	Palestine	“ 14	“ 31	2.64	0.36	1		51
17	Animate	“ 19	“ 31	2.54	0.43		12	54
18	Guymalye	“ 2	“ 17	2.33	0.21		13	65
19	Manchurian	“ 19	Sept. 6	2.67	0.36	1	4	50.5
20	Frick's	“ 12	Aug. 17	2.58	0.31		15	50
21	Spring (4-rowed)	“ 12	“ 23	2.81	0.36	1		48
22	Eufurt	“ 19	Sept. 6	2.77	0.39	1		49
23	Nepaul	“ 12	Aug. 17	3.0	0.38		11	47
24	Winter (4-rowed)	“ 12	“ 17	3.26	0.4	1	5	47.5
25	Phoenix	“ 5	“ 17	2.35	0.38		12	63
26	Sibley's Improved	“ 12	“ 29	2.61	0.39			48.5
27	Mansury	“ 12	“ 17	2.84	0.39	1		43
28	Adams' Heavy	“ 12	Sept. 2	2.71	0.3	1	3	50.5
29	Sibley's Pearl	“ 12	Aug. 23	3.57	0.38	1		50
30	Sibley's Purple	“ 19	Sept. 2	2.93	0.3	1	5	53
31	Wales	“ 12	Aug. 23	2.71	0.31	1		50.5
32	Berkley	“ 12	“ 17	2.77	0.31		10	48.5
33	Zeochrit	“ 12	“ 23	3.13	0.3	1	3	53.5
34	Perigerste	“ 19	Sept. 2	2.55	0.4	1	2	52.5
35	Black Grain	“ 5	Aug. 17	2.28	0.18		15	66.5
40	Algerian No. 2	“ 2	“ 17	2.32	0.3	1	2	46
41	“ No. 3	“ 2	“ 17	2.22	0.28		12	45.5
42	Battledore	“ 14	“ 27	2.54	0.17		11	55
46	Himalaya	“ 2	“ 17	2.45	0.26		13	65
47	Carter's Prize	“ 14	Sept. 2	2.61	0.37			51.5
48	Goldthorpe	“ 19	Aug. 23	2.72	0.26		12	50
49	. . . .	“ 5	“ 17	2.35	0.22		11	65.5
50	. . . .	“ 14	Sept. 9	3.03	0.3		8	60

TABLE XII.—*Barley, 1899.*

This gives the results of the second year's trial of all the varieties reported in Table XI. One row 10 feet long of each variety was planted. The rows were 20 inches long.

No.	NAME	Date headed		Date ripe		Height	Length of heads	Yield of grain from 10 feet of row
						feet	*feet*	*oz.*
1*	Smooth Hulless							
2*	Winnipeg No. 1							
3*	" No 2							
4*	New Zealand							
5*	Chevalier							
6*	Zealand			Sept.	8	2.2	0.3	5.5
8	Purple	July	28	"	28	2.4		16
10*	Del Norte	"	24	Aug.	30	2.2	0.2	4
11*	Triumph							
12*	Indian No. 4			Sept.	8	2.6	0.3	8.5
13	Kilma	"	20	Aug.	30	2.4	0.4	12.5
14	Scotch Annat	"	28	Sept.	8	2.5	0.37	15.5
15	Black	"	20	"	8	2.3	0.23	13
16	Palestine	"	24	Aug.	30	2.6	0.3	11
17	Animate	"	28	Sept.	8	2.4	0.35	16
18	Guymalye	"	14	Aug.	28	2.2	0.25	9
19	Manchurian	"	24	Sept.	8	2.7	0.35	19
20	Frick's	"	24	Aug.	30	2.4	0.3	8
21	Spring (4-rowed)	"	24	"	30	2.7	0.25	9.5
22	Eufurt	"	24	"	30	2.7	0.4	16
23	Nepaul	"	24	Sept.	8	2.5	0.3	12
24	Winter (4-rowed)	"	20	Aug.	28	3.2		18.5
25	Phoenix	"	14	"	28	2.6		12.5
26	Sibley's Improved	"	24	Sept.	8	2.4	0.23	15.5
27	Mansury	"	20	Aug.	28	2.8	0.35	12
28	Adams' Heavy	"	24	"	30	2.5	0.3	10.5
29	Sibley's Pearl	"	24	Sept.	8	2.3	0.33	10
30	" Purple	"	28	"	8	2.25	0.35	8
31	Wales	"	24	"	8	2.6	0.27	8
32	Berkley	"	24	"	8	2.6	0.33	9.5
33	Zeochrit	"	24	Aug.	30	2.9	0.2	12
34	Perigerste	"	24	Sept.	8	2.7	0.33	13.5
35	Black Grain	"	20	"	8	2.45	0.2	14
40	Algerian No. 2	"	20	Aug.	30	2.4	0.25	12
41	" No. 3	"	14	"	30	2.2	0.2	4.5
42	Battledore	"	24	Sept.	8	2.55	0.33	2.2
46	Himalaya	"	14	Aug.	19	2.3		7.5
47	Carter's Prize	"	24	"	30	2.8	0.35	16.5
48	Goldthorpe	"	24	"	30	2.6	0.25	17.5
49		"	14	"	19	2.6	0.2	10
50		"	14	"	19	2.9	0.2	13.5

*Injured by gophers.

TABLE XIII.—*Wheat, 1896.*

This gives the results from seed obtained from different sources. By using the New Mexico number reference may be made to Table I and the results of the same variety, grown from New Mexico seed, may be obtained. One row 50 feet long of each variety was planted The rows were 18 inches apart.

NAME	New Mexico No.	Source of seed	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row	
					ft.	*ft.*	*lbs.*	*oz*	*lbs.*	*oz.*
Amethyst		Laramie	Aug. 8	Sept. 16	4.3	0.38	11	4	2	9
“		Nevada	July 31	“ 15	3.7	0.3	10	1	3	1
Australian Club	22	Laramie	“ 25	“ 14	3.8	0.35	10	0	2	10
“ “		Nevada	“ 27	“ 15	3.5	0.3	9	14	2	14.5
Bearded Oregon		Laramie	Aug. 8	“ 16	4.0	0.35	16	10	3	6
Beryl	120	Nevada	July 27	“ 14	3.5	0.26	10	2	3	2
Black Bearded Centennial		Laramie	Aug. 8	“ 18	5.0	0.3	16	15	4	4
Blount's No. 16	16	“	“ 8	“ 16	4.0	0.3				
Blue Stem		“		Oct. 8	4.0	0.35	11	7	2	2
“ “		Nevada		Sept. 15	4.2	0.3	12	3	2	10
Chili	26	Laramie	“ 8	“ 16	4.3	0.36	13	15	2	7
“		Nevada	July 27	“ 15	3.7	0.3	12	0	2	13
Dallas	100	“		“ 15	3.6	0.34	10	9	2	10
Defiance	8	Laramie	Aug. 8	“ 16	4.1	0.35	11	9	2	14
Egyptian Flint		Nevada	July 23	“ 15	3.5	0.22	10	13	4	2
Gypsum		“		“ 15	3.8	0.33	10	8	3	2
Henson		“	“ 27	“ 15	3.26	0.18	12	1	3	7
Holbein's Improved		“	“ 27	“ 15	3.5	0.3	9	7	2	13
Improved Fife		Laramie	Aug. 8	“ 15	3.8	0.36	6	7	2	5
“ “		Colorado		“ 18	3.8	0.35				
“ “		Nevada		“ 15	3.6	0.3	10	4	2	7
Judkin	19	“	July 29	“ 15	3.65	0.36	10	3	2	10
Missogen		“		“ 15	3.25	0.18	8	11	3	0
Niagara	290	Laramie	Aug. 8	“ 16	4.3	0.45	14	6	1	13
“		Nevada	July 27	“ 15	3.6	0.3	10	11	3	5
Norfolk Red No. 1		Australia	“ 29	“ 7	3.95	0.3	1	5		10
Northcote Amber	309	Nevada		“ 12	3.5	0.33				
Nox		Laramie	Aug. 8		4.3	0.37	13	3	3	0
“		Nevada	“ 6	“ 14	3.9	0.35	10	15	3	0
Ontario		“	July 27	“ 15	4.1	0.20	11	1	3	0
Petali		“	“ 25	“ 14	3.1	0.25	9	11	3	8
Polish		Laramie	Aug. 8	“ 6	4.5	0.55	14	8	4	3
“		Nevada	July 27	“ 15	3.55	0.35	9	4	3	0
Pride of America		Laramie	“ 25		4.5	0.25	18	10	5	3
Pringle's Champion		Nevada	“ 29	“ 15	3.9	0.33	13	7	4	5
Red Clawson	112	Canada								
Red Fern		Nevada		“ 15	3.9	0.32	13	4	4	2
Red Oregon Club		“	“ 27	“ 15	3.26	0.25	9	9	2	7
Rio Grande	17	“	“ 29	“ 14	3.6	0.35	13	3	1	7.5
Ruby	58	“		“ 18	4.0	0.34	9	6	1	13
Russian Hard	509	“	“ 27	“ 14	3.4	0.21	11	1	3	12
Sardius	118	“	“ 27	“ 14	3.5	0.33	8	15	1	12
Saskatchewan		“		“ 15	4.0	0.35	12	7	3	1
“ Fife		Laramie	Aug. 10	Oct. 6	4.1	0.43	14	2	3	2
Scotch Fife		“	“ 8	Sept. 14	4.3	0.38	12	2	2	14
Scotch of Scotch		“	July 20	“ 18	3.6	0.30	8	0	1	9
Seven Head		“	“ 27	“ 16	4.4	0.25	12	4	4	2
Velvet Chaff	54	Colorado	Aug. 8	“ 14	4.0	0.38	10	12	2	2
Winnipeg Russian		Nevada	July 27	“ 15	3.5	0.35	11	7	2	4
White Australian		“	“ 27	“ 15	3.5	0.28	11	15	3	15
White Russian		Laramie	Aug. 8	Oct. 6	3.9	0.45	9	10	1	7
White Touse		“	“ 8	Sept. 16	4.35	0.35	19	0	5	7
Whittington		Nevada	July 29	“ 14	3.2	0.37	7	14	2	1

TABLE XIV.—*Oats, 1896.*

This gives the results from seed obtained from different sources. By using the New Mexico number reference may be made to Table V and the results of the same variety, grown from New Mexico seed, may be obtained. One row 50 feet long of each variety was planted. The rows were 18 inches apart.

NAME	New Mexico No.	Source of seed	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row		Weight per bu.
					ft.	*ft.*	*lbs.*	*oz.*	*lbs.*	*oz.*	*lbs.*
Baltic White		Colorado	July 20	Sept. 8	4.4	0.75	13	6	4	12	41
Bavarian		Nevada	" 25	" 17	4.3	0.95	11	13	5	2	38
Black Diamond		Ontario	Aug. 7								
Black Russian		Laramie	July 25	" 8	3.7	0.75	15	2	3	14	37
Bonanza		"	" 25		4.5	1.15					38
Chinese Hulless		"	" 13	" 4	3.25	0.65	10	2	2	13	
Clydesdale		Nevada	" 23	" 8	4.6	1.0	14	3	4	10	44
Danebrog		"	" 25	" 17	4.0	0.85	15	5	4	15	39
Danish Island		"	" 13	" 2	3.9	0.75	12	8	4	14.5	43
Early Archangel		Laramie	" 23	" 17	3.8	0.85	11	5	3	9	40
Excelsior		Nevada	" 25	" 17	4.0	0.75	14	10	4	14	40
Golden Giant		"	" 20	" 22	4.2	1.1	10	0	1	15	
" " Side		Laramie	" 24	" 22	4.5	1.1	12	6	1	7	37
Hallet's Pedigree		Nevada	" 13	" 1	3.5	0.7	11	2	4	6	43
Highbred		"	" 25	" 17	4.3	0.9	15	7	4	7	
Hopetown	46	"	" 23	" 8	4.5	0.9	12	10	4	1	43
Hulless		"	" 13	" 8	4.5	1.0	16	3	4	0	42
Illinois		"	" 25	" 30	4.85	0.85	10	15	2	5	38
Lincoln		Colorado	" 20	" 8	4.3	0.75	15	12	5	3	41
"		Nevada	" 20	" 2	3.85	0.8	14	6	4	4	
"		Laramie	" 23	" 8	4.2	0.8	10	8	3	14	
Negro Wonder		Nevada	" 11	" 8	3.6	0.7	11	14	4	2	35
" "		Laramie	" 13	" 7	3.6	0.95	10	5	3	2	
New Danish Island		"	" 23	" 17	4.0	0.85	9	14	3	7	
New Zealand	13	Nevada	" 25	" 17	4.2	0.8	12	4	4	9	
Poland White		"	" 20	" 1	3.7	0.7	11	2	5	1	39
Pringle's No. 6	8	"	" 20	" 17	4.0	0.65	10	0	4	3	40
Race Horse		Laramie	" 13	" 5	4.0	0.9	10	5	2	11	
Siberian		Nevada	" 20	" 8	4.4	0.9	12	14	4	2	
Silesian	49	"	" 11	Aug. 25	3.5	0.6	8	15	3	6	
Scelician		Colorado	" 23	Sept. 17	3.9	0.75	14	11	4	7	
South Carolina		Nevada	" 13	" 8	3.9	0.7	14	14	5	10	39
Surprise		Laramie	" 13	" 4	4.0	0.85	10	4	3	9	42
White Dutch		Nevada	" 23	" 17	4.3	0.95	11	10	2	11	41
White Snohomish		Oregon	" 13	" 8	4.2	1.0	14	1	5	3	43
" Wonder		Laramie	" 13	" 15	4.0	1.0	11	6	3	11	42
Yellow French		Colorado	" 29	Oct. 7	3.8	1.1	12	8	2	8	41
" German		"	" 17	Sept. 17	4.0	0.7	12	9	4	11	40
Zoanette Black		Nevada	" 20	Oct. 17	3.9	0.7	16	5	5	0	37

TABLE XV.—*Barley, 1896.*

This gives the results from seed obtained from different sources. By using the New Mexico number reference may be made to Table IX and the results of the same variety, grown from New Mexico seed, may be obtained. One row 50 feet long of each variety was planted. The rows were 18 inches apart.

NAME	New Mexico No.	Source of seed	Date headed	Date ripe	Height	Length of heads	Yield of straw and grain from 50 feet of row		Yield of grain from 50 feet of row		Weight per bu.
					ft.	*ft.*	*lbs*	*oz.*	*lbs.*	*oz.*	*lbs.*
Bastian's Six-Rowed		Nevada	July 17	Aug. 23	2.75	0.17	7	12	3	2	54
Black	15	"	" 11	" 24	2.8	0.25	10	11	4	5	
"		Laramie	" 6	" 25	2.7	0.3	11	11	5	1	
California		Colorado	" 1	" 31	2.3	0.2	9	6	4	15	47
Chevalier	5	Nevada	" 11	" 31	2.7	0.37	13	14	6	1	
"		Colorado	" 20	" 27	3.25	0.3	13	15	4	6	
"		Laramie	" 20	" 31	3.6	0.33	16	3	5	11	
Excelsior		Nevada	" 6	" 15	2.65	0.25	5	7	2	6	50.5
Frick's		"	" 13	" 23	3.1	0.3	10	11	4	5	
Frick's Drought Proof		"	" 11	" 31	2.61	0.26	5	9	4	5	50
Golden Grain		"	" 20	Sept. 7	2.95	0.35	14	1	5	15	53
Goldthorpe		"	" 23	" 7	3.4	0.4	13	5	5	2	
Guymale		Laramie	" 6	" 7	2.4	0.27	10	5	4	7	64
Guy Malaya		Nevada	" 23	Aug. 31	3.1	0.27	8	13	3	7	60
Guy Mayle		"	" 11	" 17	2.0	0.2	8	2	4	1	63
Highland Chief	49	"	" 20	Sept. 9	3.25	0.35	14	6	5	3	
" "		Laramie	" 23	" 7	3.3	0.36	13	6	3	15	
Italian		Nevada	" 20	Aug. 24	3.0	0.28	12	5	9	5	50
Manchurian		"	" 11	" 23	3.2	0.3	11	6	5	6	48.5
Manshury		Laramie	" 11	" 27	2.9	0.3	13	3	5	12	
"		Nevada	" 11	" 24	3.4	0.35	11	7	5	0	
Nepaul	23	Laramie	" 11	" 31	2.6	0.22	11	6	4	8	
New Black		"	" 6	" 25	2.6	0.17	12	1	4	15	63.5
New White Hulless		Nevada	" 6	" 24	2.7	0.25	10	7	4	0	56
New Zealand		Colorado	" 17	Sept. 7	3.7	0.4	12	11	5	4	54.5
Oderbencker		Nevada	" 11	Aug. 24	3.0	0.27	7	9	3	1.5	54
Purple		"	" 11	" 17	2.5	0.2	8	14	2	13	
Six-Rowed		"	" 20	" 31	2.8	0.15	12	1	6	2	48
"		Laramie	" 6	" 31	2.5	0.2	11	1	5	6	
Smooth Hulless		Nevada	" 11	" 17	2.9	0.26	9	9	3	2	64
Two-Rowed		"	" 23	Sept 7	3.1	0.35	12	7	4	14	53
"		Laramie	" 25	" 7	3.2	0.4	13	15	4	1	
Vermont Champion		"	" 11	Aug. 27	3.26	0.28	16	4	5	10	56
Winnipeg		Nevada	" 11	" 27	2.7	0.3	8	10	2	15	63
Winter		Oregon	" 25	Sept. 17	3.26	0.18					
Winter Six-Rowed		Nevada	" 11	Aug. 31	2.61	0.15	13	7	6	10	

The Cryptogams of Wyoming.

A Preliminary Report upon those Species which have been Secured to Date in the Botanical Survey of the State.

BY

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LARAMIE, WYOMING,
1900.

Cryptogams of Wyoming.

AVEN NELSON.

The first Report on the Flora of Wyoming, publish-in May, 1896, had scarcely more than a reference to the cryptogamic plants of the state. That report represented only two seasons' field-work, devoted almost exclusively to the flowering plants, of which 1,295 species were enumerated. Since it was issued, four seasons' field-work has been done, increasing so materially our knowledge of the plants of the state that said report most inadequately represents what is known of our flora. This is true both of the seed and the spore plants, but especially of the latter.

Never in the history of Rocky Mountain botany has there been such activity as during the last half decade. Field-work has been prosecuted by many collectors, from Montana to New Mexico. Not less active have those workers been who are devoting themselves to herbarium work and to bibliographical and nomenclatural studies. As a result of all this activity our publications are soon outgrown and new editions are called for to represent the ever increasing collections and the changes in nomenclature which recent studies seem to indicate as essential to justice and permanency.

The representation of Wyoming plants in the Rocky Mountain Herbarium, which is being built up at this institution, has increased to such an extent, both in respect to the number of species and the localities represented, that nothing short of a new report will adequately represent its present status. Such a report may not be undertaken now as regards the seed plants but the still relatively short list of spore plants is herein presented. This annotated list, it is believed, will prove of interest and service to many.

Unless otherwise stated the specimens upon which this report is based were collected by the writer. With the exception of a few well authenticated species, none are reported unless represented by one or more specimens in this collection (The Rocky Mountain Herbarium). Among the collections included of which we have no specimens are the fungi secured by Mr. David Griffiths, in company with Messrs. T. A. Williams and L. W. Carter, in northeastern Wyoming, the list of which was published in Bull. Torr. Bot. Club, Vol. 26 (1899), some lichens collected by Robert Reuleux in Yellowstone Park, determined and published by Dr. Stezenberger (Erythea 3:30), and some miscellaneous species from Hayden's Sixth Annual Report (1873) are also included.

For the determination of the species reported in this paper, I am indebted to a number of specialists whose names occur in connection with the groups represented. The thanks of the writer is extended to each of them and to Mr. Elias Nelson, M. A., who has greatly assisted in the preparation of the manuscript.

THE ALGAE.

No special effort has been made to collect the algae. Much material selected for use in the class-room has been located generically only. The list of algae if ever enumerated will be a long one. The waters of the state represent the very extremes of temperature and of salt content. I have no doubt that many undescribed species exist in the waters of our numerous alkali lakes. The following list represents the genera that have been noted in the material used in the botanical courses. The specific determinations (where given) are by Prof. DeAlton Saunders, except in Chara, which is by Dr. T. F. Allen.

CLASS—DIATOMEAE.

Diatoms abound in all of our waters. Navicula, Synedra, Diatoma, Pinnularia, etc., are genera well represented. The specific dedeterminations would require much time.

CLASS—CYANOPHYCEAE.

NOSTOCALES.

NOSTOCACEAE

Nostoc commune Vauch.

Very plentiful in small pools on ledges of rock: Telephone Canon, Albany Co., April 28, 1897, no. 2854.

Anabaena

This genus is not well represented though one or more species occur in spring pools.

OSCILLARIALES.

In this order, the family Oscillariaceae is represented by the following genera; Oscilllaria, Lyngbya and Phormidium. Some species of Oscillaria met with in laboratory material are probably, O. Nigra Vauch., O. Froelichii Kuetz. var., O. graci lima Kuetz. and O. tenerrima Kuetz.

CLASS—CHLOROPHYCEAE.

PROTOCOCCALES.

This order is represented in the family Protococcaceae by the genera, Protococcus and Scenedesmus, and in Hydrodictyaceae by Pediastrum.

SIPHONALES.

The genus Vaucheria, family Vaucheriaceae, is represented by a species which is probably V. geminata (Vauch.) DC.

CONJUGATALES.

DESMIDIACEAE.

Closterium acerosum (Schrank) Ehrh.

Laramie, Nov. 3, 1898, no. 5360.

Many other species in this genus occur in abundance.

Cosmarium sp.

Plants belonging to this genus have been observed at several times.

MESOCARPACEAE.

Mougeotia scalaris Hass.

Big Wind River, Fremont Co., Aug. 10, 1894, no. 5375.

ZYGNEMACEAE.

Zygnema insignis Kuetz.
Laramie, Albany Co., Oct. 13, 1896 no. 2810; Nov. 7, 1898, no. 5373.

Zygnema leiospermum De By.
Laramie, Albany Co., Nov. 3, 1898, no. 5368.

Zygnema spp.
Species of this genus are very common.

Spirogyra orbicularis (Hass.) Kuetz.
Common in the creek: Nez Perces Creek, Yellowstone National Park, July 30, 1899, no. 6239.

Spirogyra varians (Hass.) Kuetz.
City Springs, Laramie, Albany Co., Apr. 9, 1898, no. 4303.

Spirogyra spp.
This genus is well represented. A considerable number of different forms have been observed.

CONFERVOIDALES.

ULOTHRICHACEAE.

Ulothrix spp.
Several forms belonging here have been observed.

Conferva abbreviata Rab.
Laramie, Albany Co., Oct. 24, 1896, no. 2819; City Springs, Nov. 3, 1898, no. 5369.

Conferva bombycina Ag.
Laramie, Albany Co., Nov. 3, 1898, no. 5364.

CLADOPHORACEAE.

Cladophora fracta Kuetz.
In alkali ponds and lakes; Laramie, Albany Co., Oct. 11, 1896, no. 2811; Nov. 3, 1898, no. 5363.

Cladophora fracta horrida Kuetz.
Laramie, Albany Co., Nov. 3, 1898, no. 5361.

Cladophora glomerata Kuetz.
Fish Hatchery, Albany Co., Oct. 4, 1896, no. 2808; Laramie Oct. 11, no. 2813.

CHAETOPHORACEAE.

Of this family the following have been observed: a species of Chaetophora, probably C. longipila Kuetz., found on submerged grass caulms in a meadow; two species of Stigeoclonium, probably S. tenue Kuetz. and S. fastigiatum Kuetz.; a species of Draparnaldia.

OEDOGONIACEAE.

Plants belonging to the genus Oedogonium have been collected a few times at Laramie.

CLASS—CHAREAE.

CHARALES.

CHARACEAE.

Chara contraria A. Br.

In a pond: Mammoth Hot Springs, Yellowstone National Park, July 20, 1899, no. 6022.

Chara foetida A. Br.

Very frequent throughout the state in stagnant pools: Wind River, Fremont Co., Aug. 9, 1894, no. 796; Sundance Creek, Crook Co., July 6, 1896, no. 2208; Iron Mt., Laramie Co., Aug. 26, no. 2738; Platte River, Laramie Co., Aug. 27, no. 2767; Laramie, Albany Co., Sept. 7, no. 2780.

Chara fragilis Desv.

In the warm water of the creek: Nez Perces Creek, Yellowstone National Park, July 30, 1899, no. 6238.

CLASS—PHAEOPHYCEAE.

PHAEOSPORALES.

SYNGENETICACEAE.

Hydrurus foetidus (Vell.) Kirch.

Fish Hatchery, Albany Co., Oct. 4, 1896, no. 2807.

Hydrurus foetidus occidentalis Harv.

Fish Hatchery, Albany Co., Nov. 29, 1896, no. 2836.

CLASS—RHODOPHYCEAE.

This class is represented by one species, Batrachospermum gelatinosum (L.) A. F. Woods (?), of the family Batrachospermaceae, order Nemalionales.

THE MOSSES.*

CLASS—HEPATICAE.

JUNGERMANNIALES.

JUNGERMANIACEAE.

Chiloscyphus polyanthos (L) Corda.

Submerged in mountain brooks and alpine lakes: Centennial Hills, Albany Co., Aug. 20, 1896, no. 2706; La Plata Mines, Aug. 28, 1898, no. 5230.

Jungermannia cordifolia A. W. Evans.

Wolf Creek Sheridan Co., July 12, 1896, no. 2321; Centennial Hills Albany Co., Aug. 20, 1896, no. 2705; La Plata Mines, Albany Co., Aug. 29, 1898, no. 5247.

MARCHANTIALES.

MARCHANTIACEAE.

Marchantia polymorpha L.

On moist ground in woods: Head of Green River, Uinta Co., Aug. 25, 1894, no. 1051; Centennial Valley, Albany Co., Aug. 18, 1895, no. 1748; Wolf Creek, Sheridan Co., July 12, 1896, no. 2318.

Preissia hemisphaerica (L) Cogn.

On the wet, shaded banks of the lake: Lewis Lake, Yellowstone National Park, Aug. 21, 1899, no. 6601.

Conocephalus conica (L.) Dumort.

Lower Firehole Basin, Yellowstone National Park, Aug., 1872—Coulter.

CLASS—MUSCI.

SPHAGNALES.

SPHAGNACEAE.

Sphagnum acutifolium Ehrh.

Shoshone Lakes, Yellowstone National Park, Sept., 1872—Coulter.

Sphagnum fimbriatum Wils.

In Great beds on wet bottoms; Obsidian Creek, Yellowstone National Park, July 24, 1899, no. 6118; Sylvan Geysers, July 26, no. 6181.

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*I wish to acknowledge the painstaking care in the determination of the Mosses by Prof. John M. Holzinger of the State Normal School at Winona, Minn. Some of the groups were submitted by him to other specialists, viz., Dr. Cardot, Dr. True and others; the Hepaticae by Dr. Underwood.

BRYALES.

POLYTRICHACEAE.

Pogonatum alpinum Roehl.

Battle Lake Mt., Carbon Co., Aug. 17, 1897, no. 4225; La Plata Mines, Albany Co., Aug. 25, 1898, no. 5170, Aug. 28, no. 5233.

Polytrichum commune L.

Yellowstone National Park: Norris, July 25, no. 6144; Sylvan Geysers, July 26, no. 6182.

Polytrichum gracile Menz.

Sylvan Geysers, Yellowstone National Park, July 26, 1899, no. 6175.

Polytrichum Jenseni Hagen.

Beaver Lake, Yellowstone National Park, July 24, 1899, no. 6131.

Polytrichum juniperinum Willd.

Sundance Mt., Crook Co., July 3, 1896, no. 2180: Yellowstone National Park; Glen Creek, June 30, 1899, no. 5596; Yancey's July 17, no. 5935.

Polytrichum juniperinum alpinum Schimp.

La Plata Mines, Albany Co., Aug. 24, 1895, no. 1830.

Polytrichum piliferum Schreb.

La Plata Mines, Albany Co., Aug. 21, 1895, no. 1768, Aug. 28, 1898, no. 5231; Willow Creek, May 22, 1897, no. 2919; Lewis River, Yellowstone National Park, Aug. 9, 1899, no. 6369.

Polytrichum sexangulare Floerke.

La Plata Mines Albany Co., Aug. 28, 1898, no. 5232.

Polytrichum strictum Menz.

Little Goose Creek, Sheridan Co., July 16, 1896, nos. 2361 in part, 2363; Wood's Creek, Albany Co., Aug. 11 1896 no. 2071.

MNIACEAE.

Mnium affine Bland.

Centennial Valley Albany Co., Aug. 18, 1896, no. 2670.

Mnium affine rugicum Bruch & Schimp.

Snake River, Yellowstone National Park, Aug. 12, 1899, no. 6426.

Mnium cuspidatum Hedw.

Little Goose Creek, Sheridan Co., July 16, 1896, nos. 2366, 2376.

Mnium cuspidatum tenellum Kindb.

Laramie Hills, Albany Co., May 21, 1898 no. 4308.

Mnium hornum L.
La Plata Mines, Albany Co., Aug. 25, 1898, no. 5171.

Mnium serratum Laich.
La Plata Mines, Albany Co., Aug. 25, no. 5176.

Mnium subglobosum Bruch & Schimp.
Centennial Valley, Albany Co., Aug. 19, 1895, no. 1744; Centennial Hills, Aug. 20, 1896, no. 2702.

Timmia Austriaca Hedw.
Laramie Peak, Albany Co., Aug. 8, 1895, no. 1645; Wolf Creek, Sheridan Co., July 12, 1896, no. 2324; Little Goose Creek, July 16, no. 2364 in part.

Timmia Austriaca brevifolia Ren. & Card.
Cooper Hill, Albany Co., Aug. 22, 1897, no. 4265; La Plata Mines, Aug. 25, 1898, no. 5174; Tower Falls, Yellowstone National Park, July 16, 1899, no. 5913.

Aulacomnium androgynum Schwaegr.
On logs in deep woods: Yellowstone National Park; Obsidian Creek, July 24, 1899, no. 6099; Snake River, Aug. 12, no. 6429.

Aulacomnium palustre Schwaegr.
Common: Lincoln Gulch, Aug. 12, 1896, nos. 2601, 2618: Sheridan Co.; Dome Lake, July 16, 1896, no. 2417; Little Goose Creek, no. 2364 in part: Yellowstone National Park; Druid Peak, July 12, 1899, no. 5795; Nez Perces, Creek, July 29, no. 6232.

Aulacomnium papillosum Lesq. & James.
Centennial Valley, Albany Co., Aug. 19, 1895, no. 1746 in part.

MEESIACEAE.

Amblyodon dealbatus Beauv
Ferris Mts., Carbon Co., July 25, 1898 no. 4976 in part.

BARTRAMIACEAE.

Bartramia ithyphylla Bird.
La Plata Mines, Albany Co., Aug. 25, 1898, no. 5177.

Philonotis fontana Brid.
Centennial Valley, Albany Co., Aug. 18, 1895, no. 1756; Wolf Creek, Sheridan Co., July 12, 1896, no. 2317; Wood's Creek, Albany Co., Aug. 11, 1896 no. 2588; Obsidian Creek, Yellowstone National Park, July 22, 1899, no. 6062; Lewis River, Aug. 9, no. 6381.

Philonotis fontana alpina Brid.
Obsidian Creek, Yellowstone National Park, July 24, 1899, no. 6110.

Philonotis Mohriana Lesq. & James.
Battle Lake, Mt., Carbon Co., Aug. 17, 1897, no. 4202 in part.

BRYACEAE.

Bryum angustirete Kindb.
Cokeville, Uinta Co., June 11, 1898, no. 4656.

Bryum argentium L.
Laramie, Albany Co., July 29, 1897, no. 3454.

Bryum caespiticium L.
Wood's Creek, Albany Co., Aug. 9, 1897, no. 3481; Ft. Bridger, Uinta Co., June 8, 1898, no. 4595; Yellowstone Lake, Aug. 23, 1899, no. 6640.

Bryum cirrhatum Hoppe & Hornsch.
La Plata Mines, Albany. Co., Aug. 28, 1898, no. 5235; Cummins, Albany Co., July 30, 1895, no. 1538 in part.

Bryum crassirameum Ren. & Card.
Ferr's Mts., Carbon Co., July 25, 1898, no. 4977.

Bryum inclinatum Bruch & Schimp.
Laramie Hills, Albany Co., June 13, 1896, no. 1928.

Bryum intermedium Brid.
Centennial Valley, Albany Co., June 18, 1895, no. 1263.

Bryum Oreganum Sulliv.
Centennial Hills, Albany Co., Aug. 20, 1896, nos. 2708, 2707 in part; Dome Lake, Sheridan Co., July 16, 1896, no. 2416 in part.

Bryum pendulum Schimp.
Little Goose Creek, Sheridan Co., July 16, 1896, no. 2362; Buffalo, Johnson Co., July 25, 1896, no. 2505; Centennial Valley, Albany Co., Aug. 17, 1896, no. 2654.

Bryum pseudotriquetrium Schwaegr.
Centennial Valley, Albany Co., June 8, 1895, no. 1259.

Bryum torguescens Bruch & Schimp.
On damp ground in woods; Druid Peak, Yellowstone National Park, July 12, 1899, no. 5801.

Bryum turbinatum latifolium Schimp.
Ferris Mt., Carbon Co., July 25, 1898, no. 4978.

Leptobryum pyriforme Schimp.

Centennial Valley, Albany Co., Aug. 18, 1895, nos. 1717, 1723 in part; Centennial Hills, Albany Co., Aug. 20, 1896, no. 2707 in part; Wood's Creek, Aug. 11, no. 2589 in part; Yellowstone Lake, Aug. 11, no. 2589 in part; Yellowstone Lake, Aug. 24, 1899, no. 6645.

FUNARIACEAE.

Funaria hygrometrica Hedw.

Sheridan Co.: Wolf Creek, July 12, 1896, no. 2322a; Dome Lake, July 16, no. 2322.

WEBERACEAE.

Webera albicans Schimp.

Centennial Valley, Albany Co., June 9, 1895, no. 1285; North Vermillion Creek, Sweetwater Co., July 17, 1897, no. 3576; Evanston, Uinta Co., July 27, 1897, no. 4128 in part; Battle Lake, Carbon Co., Aug. 16, 1897, no. 4180; Hat Six Falls, Natrona Co., Aug 7, 1898, no. 5035; La Plata Mines, Albany Co., Aug. 25, 1898, no. 5248.

Webera cruda Schimp.

Centennial Valley, Albany Co., Aug. 17, 1896, no. 2657.

Webera nutans Hedw.

Sundance Mt., Crook Co., July 3, 1896, no. 2173 in part; Lincoln Gulch, Albany Co., Aug. 13, 1896, no. 2629; La Plata Mines, Aug. 25, 1898, no. 5175; Yellowstone National Park; Trout Lake, July 14, 1899, no. 5846; Beaver Lake, July 24, no. 6124; Upper Geyser Basin, July 31, no. 6259.

TORTULACEAE.

Barbula amplexa Lesq.

La Plata Mines, Albany Co., Aug. 28, 1898, no. 5234.

Barbula mucronifolia Bruch & Schimp.

Cooper Hill, Albany Co., Aug. 22, 1897, no. 4995; Cummins, July 30, 1895, no. 1538 in part.

Barbula Muelleri Bruch & Schimp.

Sundance Mt., Crook Co., July 3, 1896, no. 2181; Hat Six Falls, Natrona Co., Aug. 7, 1898, no. 5034.

Barbula ruralis Hedw.

Near Rock Springs, Sweetwater Co., July 25, 1897, no. 3598.

Desmatodon Porteri James.

Cummins, Albany Co., July 30, 1895, no. 1538 in part.

Leptotrichum flexicaule Hampe.

Tower Falls, Yellowstone National Park, July 16, 1899, no. 5912.

Didymodon rubellus Bruch & Schimp.

Head of Pole Creek, Albany Co., July 22, 1897, no. 3438.

DICRANACEAE.

Gymnostomum curvirostrum Hedw.

South Butte, Sweetwater Co., July 13, 1897, no. 3549.

Dicranoweisia cirrhata Lindb.

On rocks; Specimen Ridge, Yellowstone National Park, July 15, 1899, no. 5892.

Dicranoweisia crispula Lindb

Sheep Mt., Albany Co., July 3, 1897, no. 3312.

Dichodontium Olympicum Ren & Card.

La Plata Mines, Albany Co., Aug. 25, 1898, no. 5178.

Dicranum Bonjeani De Not.

On dry shaded ground; Beaver Lake, Yellowstone National Park, July 24, 1899, no. 6125.

Dicranum neglectum Jur.

On cliffs; Yancey's Yellowstone National Park, July 17, 1899, no. 5936.

Ceratodon purpureus Brid.

Sheridan Experiment Farm, Sheridan Co., July, 1894, no. 1211 in part; Sundance Mt., Crook Co., July 3, 1896, no. 2168; Wood's Creek, Albany Co., Aug. 11, 1896, no. 2589 in part.

Distichium capillaceum Bruch & Schimp.

Wolf Creek Canon, Sheridan Co., July 12, 1896, nos. 2298, 2307, 2315; Buffalo, Johnson Co., July 25, no. 2507 in part; Laramie Hills, Albany Co., May 31, 1898, no. 4307; La Plata Mines, Aug. 25, no. 5173; Druid Peak, Yellowstone National Park, July 12, 1899, no. 5803.

Distichium inclinatum Bruch & Schimp.

On rocks, Mammoth Hot Springs, Yellowstone National Park, July 20, 1899, no. 6026.

GRIMMIACEAE.

Racomitrium canescens Brid.

Nez Perces Creek, Yellowstone National Park, July 29, 1899, no. 6210.

Racomitrium fasiculare Brid.

Jackson's Lake, Uinta Co., Sept., 1872—Coulter.

Grimmia alpestris Schleich.
Centennial Hills, Albany Co., Aug. 20, 1896, no. 2699.

Grimmia apocarpa Hedw.
Dome Lake, Sheridan Co., July 16, 1896, no. 2416 in part.

Grimmia calyptrata Hook.
Willow Creek, Albany Co., May 22, 1897, no. 2917.

Grimmia commutata Hueben.
La Plata Mines, Albany Co., Aug. 29, 1898, no. 5243.

Grimmia conferta Funck.
Yellowstone Valley, Aug. 1872—Coulter.

Grimmia Scouleri Meull.
Yellowstone Valley, Aug., 1872—Coulter.

Scouleria aquatica Hook.
Dome Lake, Sheridan Co., July 16, 1986, no. 2416 in part.

Encalypta ciliata Hedw.
Sundance Mt., Crook Co., July 3, 1896, no. 2173 in part.

Encalypta rhabdocarpa Schwaegr.
Little Goose Creek, Sheridan Co., July 16, 1896, no. 2361 in part; Telephone Canon, Albany Co., Apr. 28, 1897, no. 2855.

Orthotrichum cupulatum Hoffm. ?
Willow Creek, Albany Co., May 22, 1897, no. 2918.

Orthotrichum laevigatum Zett.
Druid Peak, Yellowstone National Park, July 2, 1899, no. 5791.

HYPNACEAE.

Pseudoleskea oligoclada Lindb.
Centennial Hills, Albany Co., Aug. 18, 1895, no. 1724.

Thuidium Blandovii (Web. & Mohr.) Bruch.
Centennial Valley, Albany Co., Aug. 19, 1895, no. 1746 in part; Centennial Hills, Aug. 20, 1896, no. 2700.

Leskia n. sp. (?)
Hat Six Falls, Natrona Co., Aug. 7, 1898, no. 5036.

Camptothecium aeneum (Nitt.) Lesq & James.
Sundance Mt., Crook Co., July 3, 1896, no. 2166; Hat Six Falls, Natrona Co., Aug. 7, 1898, no. 5039; La Plata Mines, Albany Co., Aug. 30, 1898, no. 5265.

Camptothecium lutescens Bruch & Schimp.
On moist ground. Mammoth Hot Springs, Yellowstone National Park, July 21, 1899, no. 6041.

Brachythecium acutum Sulliv.
Centennial Valley, Albany Co., Aug. 17, 1895, no. 1698.

Brachythecium rivulare Bruch & Schimp.
Albany Co.: Laramie Peake, Aug. 7, 1895, no. 1622; Centennial Hills, Aug. 20, 1896, no. 2701; Laramie, Sept. 15, 1897, no. 4283.

Brachythecium salebrosum Bruch. & Schimp.
Wood's Creek, Albany Co., Aug. 9, 1897, no. 3480; The Thunderer Yellowstone National Park, July 13, 1899, no. 5812.

Brachythecium Utahense James.
Centennial Hills, Albany Co., Aug. 20, 1896, nos. 2712 2716.

Raphidostegium recurvans Lesq. & James.
Lincoln Gulch, Albany Co., Aug. 13, 1896, no. 2628.

Amblystegium filicinum Lindb. var.
Ferris Mts., Carbon Co., July 25, 1898, no. 4976 in part.

Amblystegium hygraphilum Schimp. (?)
In a bog; Yanceys' Yellowstone National Park, July 16, 1899, no. 5903.

Amblystegium Kochii Schimp.
Sundance Creek, Crook Co., July 7, 1896, no. 2233; Centennial Valley, Albany Co., Aug. 18, 1896, no. 2671.

Amblystegium porphyrrhizum Lindb.
On a moist, rotten log; Laramie Hills, Albany Co., June 13, 1896, no. 1929.

Amblystegium serpens Bruch & Schimp.
Ferris Mts., Carbon Co., July 25, 1898, no. 4979 in part.

Amblystegium varium Lindb.
Ferris Mts., Carbon Co., July 25, 1898, no. 4979 in part.

Hypnum aduncum Hedw
Cooper Hill, Albany Co., Aug. 22, 1897, no. 4266; Ft. Bridger, Uinta Co., June 9, 1898, no. 4609; Cokeville, June 11, no. 4624; La Plata Mines, Albany Co., Aug. 30, 1898, no. 5262; Obsidian Creek, Yellowstone National Park, July 24, 1899, no. 6106.

Hypnnm aduncum Kneiffii Schimp.
Little Laramie River, Albany Co., Sept. 14, 1896, no. 4294.

Hypnum arcticum Sommerf.
Centennial Hills, Albany Co., Aug. 20, 1896, no. 2704.

Hypnum callichroum Brid. (?)
Evanston, Uinta Co., July 27, 1897, no. 4128 in part.

Hypnum capillifolium Warnst.
Dome Lake, Sheridan Co., July 16, 1896, no. 2408; Wagon Hound Creek, Carbon Co., Aug. 21, 1897, no. 4262; Evanston, Uinta Co., Aug. 31, 1897, no. 4277.

Hypnum commutatum Hedw.
Union Pass, Fremont Co., Aug. 12, 1894, no. 1078.

Hypnum depressulum Muell.
Laramie, Hills, Albany Co., June 13, 1896, no. 1924; La Plata Mines, Aug. 25, 1898, no. 5172.

Hypnum filicinum L.
Green Mt., Crook Co., July 6, 1896, nos. 2221, 2222.

Hypnum fluitans L.
Snake River, Yellowstone National Park, Aug. 12, 1899, no. 6485.

Hypnum hispidulum Brid
Beaver Creek, Weston Co., July 30, 1896, no. 2563; Cooper Hill, Albany Co., Aug. 22, 1897, no. 4296.

Hypnum laetum Brid.
Yellowstone Valley, Aug. 23, 1872—Coulter.

Hypnum palustre Hedw.
Battle Lake Mt., Carbon Co., Aug. 17, 1897, no. 4202 in part.

Hypnum plicatile Lesq. & James
Cummins, Albany Co., July 29, 1895, no. 1507.

Hypnum revolutum.
Head of Pole Creek, Albany Co., May 5, 1897, no. 2861.

Hypnum stellatum Schreb.
Beaver Creek, Weston Co., July 30, 1896, no. 2556.

Hypnum symmetricum Ren. & Card.
Dome Lake, Sheridan Co., July 16, 1896, no. 2416, no. 2416 in part.

Hypnum uncinatum Hedw.
La Plata Mines, Albany Co., Aug. 29, 1898, no. 5244; Tower Falls, Yellowstone National Park, July 16, 1899, no. 5911.

Limnobium (?) sp.
Hat Six Falls, Natrona Co., Aug. 7, 1898, no. 5038.

STEREODONTACEAE.

Hylocomium splendens Bruch & Schimp.
Wolf Creek Canon, Sheridan Co., July 12, 1896, no. 2306.

Plagiothecium Sullivantiae Schimp.
La Plata Mines, Albany Co., Aug. 29, 1898, no. 5242.

NECKERACEAE.

Climacium Americanum Brid
Centennial Valley, Albany Co., Aug. 18, 1895, no. 1724.

Climacium dendroides Web. & Mohr.
Upper Canon of the Madison River, Aug., 1872—Coulter.

Fontinalis antipyretica Oregonensis Ren. & Card. (?)
Lincoln Gulch, Albany Co., Aug. 12, 1896, no. 2619.

Fontinalis Duriali Schimp.
North Vermillion Creek, Sweetwater Co., July 17, 1897, no. 3577

Fontinalis hypnoides Hartm.
Evanston, Uinta Co., May 29, 1897, no. 3004; Albany Co., Aug. 7, 1897.

Fontinalis Neo-Mexicana Sulliv. & Lesq.
Little Goose Creek, Sheridan Co., July 16, 1896, no. 2371; Buffalo, Johnson Co., July 25, 1896 no. 2506.

Fontinalis Neo-Mexicana Columbica Cardot.
In flowing water; Spring Creek Yellowstone National Park, Aug. 3, 1899.

Fontinalis nitida Lindb.
Moorcraft, Crook Co., July 8, 1896, no. 2248.

Hedwigia ciliata Ehrh.
Shoshone Lake, Yellowstone National Park, Sept., 1872—Coulter.

THE FUNGI.*

Dr. Underwood, in his recently published book, Moulds, Mildews and Mushrooms, gives a brief summary of the work that has been done upon the fungi in the different states and countries of North America. Of Wyoming he writes as follows: "Comparatively little has been done in the direction of local study of fungi in this state. Professor Aven Nelson has collected a few species in connection with his work on the higher flora of the state,† and Prof. T. A. Williams and David Griffiths have collected largely the parasitic fungi in connection with other work. Most of these collections are as yet unstudied." Little as has been done in this state we are not worse off than some of the other and much older states, some of which Dr. Underwood designates as *terrae incognitae.* With the publilation of the present list, we may at least say that a beginning has been made.

But it is only a beginning. A region of 100,000 square miles in extent, with a climate varying according to the conformation, the exposure and the altitude and latitude of the land represented gives a flora as varied as its topography. Unless the number of workers in this field is vastly increased it will be many years yet before the state is measureably well known.

The fungi parasitic upon the higher plants, especially upon the crop plants, are always the first to receive consideration. The smuts, the rusts and the mildews attract attention by reason of the disastrous effect that they produce in the garden, the orchard and the field. Those that are the most to be dreaded usually find their way into new territory in connection with the introduction of their natral hosts. The remarkable immunity that this state has so far enjoyed is to be associated with the climatic conditions which are, in a measure, unfavorable to the development of the parasitic fungi. Those which are epithytic or infect the host plant through its external tissues are not particularly abundant in Wyoming. These need for their highest development a moist, warm climate. However, a number of species have adapted themselves even to the conditions that prevail on the arid plains as well as to those of the colder, moist mountain regions. These are of interest since they show that even our climatic conditions must not be expected to secure for our crops complete immunity. That class of *endoparasites*, represented by the smuts, which pass their life history, in large part, wholly within the tissues of the host may become as troublesome here as elsewhere.

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*For the determination of the parasitic fungi we are indebted to Dr. J. B. Ellis of Newfield, N. J., while the few species of woody and fleshy forms were examined by Dr. L. M. Underwood and Dr. C. H. Peck, respectively.

†The statement must be based upon and have reference to the exceedingly short list published in Bulletin 28 of this Station, the report referred to above.

THE FLESHY FUNGI.

Mushrooms, toadstools, etc., seem to be very abundant in the state but their study is attended by almost insurmountable difficulties. Only collectors realize how hard it is to so dry specimens as to preserve them and yet leave them in condition for study. Such plants should be studied in the fresh state, but this is also nearly precluded with us. They are a product found almost exclusively in the woods and as such collecting grounds are from 30 to 50 miles distant and only to be visited with team and camp outfit it will be seen that fresh specimens for the laboratory are hardly to be considered.

Because of the difficulties attending their study no literature has been produced especially devoted to this part of our flora. What is known is so widely scattered in all sorts of publications that access to such information is difficult and implies extensive library facilities. Difficult as it is to bring the plants to the laboratory it would be more difficult to take the library and laboratory to the plants. How these obstacles are to be met is for the future to solve but in the meantime this much is known, that many esculent species occur in the greatest abundance in our Coniferous forests.

Clavarias of the most delightful flavor are met with and are freely eaten by many who find them recommended by this fact solely, that browsing animals (deer) feed upon them unharmed. If one may take this as a safe test there are among the Agarics, the Boleti and the Lycoperdons many other species worthy of our acquaintance.

Besides the species enumerated in the following list of fungi, many more will undoubtedly be found when the lower altitudes of the state, as yet largely unexplored, shall have been carefully worked.

CLASS—PHYCOMYCETES.

PERONOSPORALES.

ALBUGINACEAE.

Albugo candida (Pers.) Kuntze,

On Thlaspi glaucum; Battle Lake, Carbon Co., Aug. 16, 1897 no. 4177.

CLASS—ASCOMYCETES.

EXOASCALES.

EXOASCACEAE.

Taphrina Quercus (Cke.) E. & E.

On Quercus macrocarpa; Sundance, Crook Co., July 3, 1896, no 2167.

PERISPORIALES.

ERYSIBACEAE.

Podosphaera Allii Griffiths.

On Allium brevistylum; Williams and Griffiths, Big Horn Mts. near Buffalo, Johnson Co.

Podosphaera Oxyacanthae (DC.) De By.

David Griffiths: on Spiraea lucida, S. Fork Piney Creek, Sheridan Co.; on Prunus demissa, S. Fork Piney Creek; on Crataegus rivularis, Buttes.

Sphaerotheca Castagnei Lev.

Reported by David Griffiths from Sheridan, Johnson and Creek Counties, on eight different hosts.

Sphaerotheca Epilobii (Link.) De By.

On Epilobium adenocaulon; David Griffiths, Buffalo, Johnson Co.

Sphaerotheca Humuli (DC.) Burrill.

On Pedicularis sp.; Teton Mts., Uinta Co., Aug. 16, 1899, no. 6526: also by David Griffiths, on Viola Cadensis, Buffalo, Johnson Co.; on Geranium Richardsoni, Bear Lodge Mts., Crook Co.; on Humulus Lupulus, Buffalo.

Sphaerotheca mors-uvae (Schw.) B. & C.

On Ribes lacustri; David Griffiths, Buffalo, Johnson Co.

Sphaerotheca pannosa (Wallr.) Fr.

On Rosa Woodsii; David Griffiths, Ft. McKinney, Johnson Co.

Phyllactinia suffulta (Reb.) Sacc.

On Amelanchier alnifolia: Sand Creek, Albany Co., Aug. 8, 1896, no. 2049; Laramie Hills, Albany Co., Sept. 13, 1899, no. 6908: on Betula occidentalis; David Griffiths, Ft. McKinney, Johnson Co.

Uncinula Salicis (DC.) Wint.

David Griffiths: on Salix sp., Buttes, Crook Co.; on Populus balsamifera, Buffalo, Johnson Co.

Microsphaera Alni (DC.) Wint.

On Lonicera glaucescens; David Griffiths, Bear Lodge Mts., Crook Co.

Microsphaera diffusa C. & P.

David Griffiths: on Vicia Americana, Buffalo, Johnson Co.; on Glycyrrhiza lipidota, Buttes, Crook Co.

Microsphaera quercina (Schw.) Burrill

On Quercus macrocarpa; David Griffiths, Buttes, Crook Co.

Microsphaera Ravenelii Berk

On Lathyrus venosus; David Griffiths, Bear Lodge Mts., Crook Co.

Microsphaera Vaccinii C. & P.

On Vaccinium microphyllum; David Griffiths, Buffalo, Johnson Co.

Erysibe Cichoracearum DC.

Common: on Hydrophyllum occidentale, Cummins, Albany Co., July 29, 1895, no. 1516; on Grindelia sp., J. Johnson's ranch, Albany Co., Aug. 8, 1897, no. 3471a; on Prryocoma lanceolata, Laramie, Albany Co., Sept. 6, 1898, no. 5287; on Lapula sp., Teton Mts., Uinta Co., Aug. 16 1899, no. 6495. Also, collected by David Griffiths on twelve different hosts in Sheridan, Johnson and Crook counties.

Erysibe communis (Wallr.) Fr.

Very abundant and widely distributed: on Geranium incisum, Pass Creek, Sheridan Co., July 21, 1896, no. 2475; on Lydodesmia sp., Cabbria Canon, Converse Co., July 29, 1896, no. 2520; on Trifolium longipes, Evanston, Uinta Co., July 28, 1897, no. 3866a; on Lonicera involucrata, Evanston, July 27, no. 4124; on Anogra pallida, J. Johnson's ranch, Albany Co., Aug. 8, 1897, no. 4293; on Chrysothamnus Vaseyi, Laramie Hills, Albany Co., Sept. 28, 1897, no. 4301; on Polygonum aviculare, Laramie, Sept. 15, 1899, no. 6889. Also, by David Griffiths on seven other hosts in Johnson and Crook counties.

Erysibe Galeopsidis DC.

On Stachys palustris; David Griffiths, Ft. McKinney, Johnson Co.

Erysibe graminis DC.

On Poa nemoralis; Grand Encampment Creek, Carbon Co., Aug. 13, 1897, no. 3983a; David Griffiths, on three other hosts in Johnson Co.

PERISPORIACEAE.

Dimerosporium Collinsii (Schw.) E. & E.

On Amelanchier alnifolia; Sundance Mt., Crook Co., July 3, 1896, no. 2172.

Capnodium salicinum A. & S.

On the bark of living Populas tremuloides; Willow Creek, Albany Co., May 22, 1897, no. 2922.

Lasiobotrys Lonicerae Kze.

On Symphoricarpos sp.; Evanston, Uinta Co., July 27, 1897, no. 4112.

SPHAERIALES.

CUCURBITARIACEAE.

Otthia morbosa (Schw.) E. & E.

On Prunus Americana; Pass Creek, Sheridan Co., July 21, 1896, no. 2492: on Prunus demissa; Pass Creek, no. 2493.

SPHAERELLOIDEACEAE.

Sphaerella Fassiana De Not.

On Festuca Kingii; Sheep Mt., Albany Co., July 3, 1897, no. 3300a.

Sphaeria Coulteri Peck.

"Leaves and branchlets of pines;" near Yellowstone Lake, Aug. 1872—Coulter.

ASCOLICHENALES.*

CALICIACEAE.

Acolium tigillare (Ach.) De Not.

On dead dry wood; Telephone Canon, Albany Co., May 29, 1897, no. 2935.

CLADONIACEAE.

Stereocaulon tomentosum (Fr.) Th. Fr.

In small mats in pine woods: Lincoln Gulch, Albany Co., Aug. 13, 1896, no. 2620; Centennial Hills, Aug. 20, no. 2690.

Cladonia cariosa (Ach.) Spreng.

Sundance Mt., Crook Co., July 3, 1896, no. 2175.

Cladonia deformis (L.) Hoffm.

On moist rotten logs in the woods: Yellowstone Park; Glen Creek, July 1, 1899, no. 5616, Beaver Lake, July 24, no. 6123.

Clodonia degenerans Floerk.

Obsidian Creek, Yellowstone National Park, July 24, 1899, no. 6119.

Cladonia fimbriata coniocraea (Floerk) Wainio.

Centennial Hills, Albany Co., Aug. 20, 1896, no. 2710; Yancey's, Yellowstone National Park, July 17, 1899, no. 5932.

Cladonia fimbriata simplex (Weis.) Wainio.

Sundance Mt., Crook Co., July 3, 1896, nos. 2170, 2171; Lincoln Gulch, Albany Co., Aug. 12, 1896, nos. 2607, 2608; Battle Lake, Carbon Co., Aug. 15, 1897, no. 4167.

Cladonia gracilis (L) Nyl.

On moist ground; Centennial Hills, Albany Co., Aug. 20, 1896, no. 2711.

***This list of Lichens, though not exhaustive, will give a fair notion of the prevailing forms. For their determination we are under many obligations to Prof. T. A. Williams of the Division of Agrostology of the U. S. Department of Agriculture .**

Cladonia pyxidata (L.) Fr.

Centennial Hills, Albany Co., Aug. 18, 1895, no. 1749, Aug. 20, 1896, no. 2711.; Dome Lake, Sheridan Co., July 16, 1896, no. 2418; Sheep Mt., Albany Co., July 3, 1897, no. 3310; La Plata Mines, Aug. 28, 1898, no. 5229.

Cladonia sylvatica (L.) Hoffm.

Yellowstone National Park: Norris, July 25, 1898, no. 6149; Artist's Paint Pots, July 20, no. 6167.

Cladonia verticillata cervicornis (Ach.) Floerk.?

Upper Geyser Basin, Yellowstone National Park, July 31, 1899, no. 6266.

LECIDIACEAE.

Lecidea atrobrunnea (D. C.) Schaer

Ferris Mt., Carbon Co., Nov. 16, 1897, nos. 4286, 4287, W. C. Knight; Dunraven Peak, Yellowstone National Park, Aug. 27, 1899, no. 6729.

Lecidea enteroleuca Fr.

Bitter Creek, Sweetwater Co., June 3, 1897, no. 3112.

Lecidea speira

Wamsutter, Sweetwater Co., June 4, 1897, no. 3131 a.

Umbilicaria polyphylla Hoffm.

Shoshone Lake, Yellowstone National Park, Sept., 1872—Coulter.

Umbillicaria rugifera Nyl.

Ferris Mts., Nov. 16, 1897, no. 4292, W. C. Knight.

Umbillicaria vellea (L.) Nyl.

Sundance Mt., Crook Co., July 3, 1896, no. 2174: Yellowstone National Park; Gibbon Meadow, July 28, 1899, no. 6193, Yellowstone Canon, Aug. 24, no. 6664.

PHYSCIACEAE.

Rinodina oreina (Ach.) Mass.

On rocks; Laramie Hills, Albany Co., Jan., 1896, no. 2832 in part; Ferris Mts., Carbon Co., July 24, 1898, no 4965.

Rinodina turfacea (Wahl.) Koerb.

Centennial Hills, Albany Co., Aug. 17, 1895, no. 1713.

Placodium cladodes Tuck.

Teton Mts., Uinta Co.—Coulter.

Placodium elegans (Link.) DC.

Dome Lake, Sheridan Co., July 18, 1896, no. 2451; Sheep Mt., Albany Co., July 3, 1897, no. 3347; Ferris Mts., Carbon Co., Nov. 16, 1897, no. 4291.

Placodium elegans trachyphyllum Tuck.

Laramie Hills, Albany Co., Jan., 1896, no. 2835; Evanston, Uinta Co., May 29, 1897, no. 2985.

Placodium fulgens trachyphyllum Tuck.

Laramie Hills, Albany Co., May 15, 1897, no. 2866.

Placodium vitellinum (Ehrh.)

On rocks; Laramie Hills, Albany Co., May 15, 1897, no. 2874.

Physcia hispida (Schreb.) Tuck

Sheep Mt., Albany Co., July 3, 1897, nos. 3349 b., 3348; Little Laramie River, July 4, 1897, no. 3343.

Physcia stellaris L.

On rocks: Willow Creek, Albany Co., May 22, 1897, no. 2927; Telephone Canon, May 29, 1897, no. 2934.

Theloschistes lychneus (Ach) Tuck.

On dead twigs and bark of trees: Telephone Canon, Albany Co., Apr. 28, 1897, no. 2857, May 29, no. 2933; Centennial Valley, July 3, 1897, no. 3345; Evanston, Uinta Co., May 29, 1897, no. 3018.

Theloschistes polycarpus (Ehrh.) Tuck.

On dead twigs and bark of trees: Albany Co.: Laramie Hills, Jan., 1896, no. 2834; Willow Creek, May 22, 1897, no. 2928; Sheep Mt., July 3, no. 3349 a: Sweetwater Co.; Wamsutter, June 4, 1897, no. 3131 b.

PARMELIACEAE.

Urceolaria seraposa (L.) Nyl.

On gravelly soil; Willow Creek, Albany Co., May 22, 1897, no. 292.

Lecanora calcarea contorta Fr.

On loose stones; Medicine Bow, Carbon Co., June 5, 1897, no. 3144.

Lecanora chlorophana (Wahl.) Ach.

On rocks, very common: Sundance Mt., Crook Co., July 7, 1896, no. 2238; Laramie Hills, Albany Co., Jan., 1896, no. 2832 in part; Ferris Mts., Carbon Co., Nov. 16, 1897, no. 4288, W. C. Knight; Specimen Ridge, Yellowstone National Park, July 15, 1899, no. 5894.

Lecanora coarctata (Sm.) Ach.

"On rocks, Yellowstone Park"—Robert Reuleux.

Lecanora fuscata (Schrad.) Th. Fr.

On rocks; Ferris Mts., Carbon Co., Nov. 16, no. 4285 in part, W. C. Knight.

Lecanora Hageni Ach.

On dead stems of shrub; Wamsutter, Sweetwater Co., June 4, 1897, no. 3131 a.

Lecanora Haydeni Tuck.

Loose on the ground in Laramie Hills, Albany Co., May 10, 1898, no. 4306.

Lecanora hypoptoides Nyl.

"On dead wood, Yellowstone Park"—Robert Reuleux.

Lecanora muralis (Schreb.) Schaer.

On rocks; Ferris Mts., Carbon Co., Nov. 16, 1897, no. 4285 in part (W. C. Knight), july 24, 1898, no. 4964.

Lecauora polytropa illusoria Ach.

"On rocks, Yellowstone Park"—Robert Reuleux.

Lecanora rubina (Vill.) Ach.

On rocks: Willow Creek, Albany Co., May 22, 1897, no. 2926; J. Johnson's Ranch, Aug. 7, no. 3472.

Lecanora rubina opaca Ach.

On rocks: Bitter Creek, Sweetwater Co., June 3, 1897, no. 3111; Sheep Mt., Albany Co., July 3, 1897, no. 3111; Dunraven Peak, Yellowstone National Park, Aug. 27, 1899, no. 6728.

Lecanora Schleicheri (Ach.) Nyl.

On gravelly ground; Willow Creek, Albany Co., May 22, 1897, no. 2920.

Lecanora xanthophana dealbatu Tuck.

On rocks: Sweetwater Co.: Green River, May 30, 1897, no. 3037; Bitter Creek, June 3, no. 3110; Wamsutter, June 4, no. 3125: Specimen Ridge, Yellowstone National Park, July 15, 1899, no. 5893.

Parmelia conspersa (Ehrh.) Nyl.

Very common and widely distributed, on rocks: Pole Creek, Albany Co., July 1, 1895, no. 1387; Sundance Mt., Crook Co., July 7, 1896, no. 2237; Ferris Mts., Carbon Co., Nov. 16, 1898, no. 4290; (W. C. Knight), July 24, 1898, no. 4963; La Plata Mines Aug. 30, 1898, no.

5267; Gibbon Meadow, Yellowstone National Park, July 28, 1899, no. 6192.

Parmelia mollinscula Ach.
Loose on the ground, very common on the plains; Laramie, Albany Co., July 23, 1895, no. 1429; Red Desert, Sweetwater Co., June 3, 1897, no. 3124.

Parmelia olivacea aspidota Ach.
On twigs and stems: Albany Co.; Willow Creek, May 22, 1897, no. 2932, Sheep Mt., July 3, no. 3308, Centennial Valley, July 3, no. 3346.

Parmelia saredìata (Ach) Nyl.
On rocks; Willow Creek, Albany Co., May 22, 1897, no. 2929.

Parmelia saxatilis sulcata (Tayl.) Nyl.
Sundance Mt., Crook Co., July 3, 1896, no. 2161.

Parmelia tiliacea (Hoffm.) Floerk.
On rocks; Sundance Mt., Crook Co., July 3, 1896, no. 2179.

Cetraria Islandica Ach.
On moist ground under stunted spruce, at 10,000 ft. alt.; La Plata Mines, Albany Co., Aug. 29, 1898, no. 5249.

Cetraria Juniperina Pinastri Ach.
Sundance Mt., Crook Co., July 3, 1896, no. 2184.

Cetraria nivalis (L.) Ach.
La Plata Mines, Albany Co., Aug. 28, 1898, no. 5227.

Everina vulpina (L.) Ach.
Centennial Valley, Albany Co., Aug. 17, 1895, no. 1699: Yellowstone Park; Undine Falls, July 6, 1899, no. 5689, Dunraven Peak, Aug. 27, no. 6701.

Alectoria jubata Fr.
Shoshone Lake, Yellowstone National Park, Sept., 1872—Coulter.

Usnea barbata hirta Fr.
Sundance Mt., Crook Co., July 3, 1896, no. 2162.

VERRUCARIACEAE.

Endocarpum miniatum (L.) Schaer
Laramie Hills, Albany Co., May 15, 1897, no. 2870.

PANNARIACEAE.

Pannaria brunnea (Sw.) Mass.
On wet ground; Centennial Hills, Albany Co., Aug. 20, 1896, no. 2698.

Pannaria Hypnarum (Hoffm.)

On wet ground; La Plata Mines, Albany Co., Aug. 25, 1898, no. 5179.

Peltigera aphthosa (L.) Hoffm.

On moist ground in woods, very common: Albany Co.; Centennial Valley, Aug. 18, 1895, no. 1749, Laramie Peak, Aug. 8, 1895. no. 1644, Centennial Hills, Aug. 20, 1896 no. 2709: Tower Falls, Yellowstone National Park, July 16, 1899, no. 5907.

Peltigera canina (L.) Hoffm.

On moist ground: Cummins, Albany Co., July 29, 1895, no. 1508; Dome Lake, Sheridan Co., July 16, 1896, no. 2419.

Peltigera rufescens (Neck.) Hoffm.

Druid Peak, Yellowstone National Park, July 12, 1899. no. 5798.

HYSTERIALES.

HYSTERIACEAE.

Hysterium Pinastri Fr.

"On pine leaves;" "near Yellowstone Lake, August 23." 1872—Coulter.

PHACIDIALES.

PHACIDIACEAE.

Rhytisma salicinum (Pers.) Fr.

On Salix sp.; Sand Creek, Carbon Co., July 26, 1898. no. 4983. On Salix arctica petraea; La Plata Mines, Albany Co., Aug. 28, 1898, no. 5219.

PEZIZALES.

MOLLISIACEAE.

Pseudopeziza Medicaginis (Lib.) Sacc.

On Medicago sativa; Laramie Experiment Farm, Albany Co., Sept. 14, 1898, no. 5344.

CENANGIACEAE.

Cenangella deformata Pk.

On the bark of Juniperus scopulorum; Laramie Hills, Albany Co., March 6, 1898, no. 4300.

HELVELLALES.

HELVELLACEAE.

Morchella conica Pers.

In moist ground; Laramie Albany Co., May 31, 1897, no. 2944.

CLASS—FUNGI IMPERFECTI.

SPHAEROPSIDALES.

SPHAEROPSIDACEAE.

Phyllosticta ferax E. & E.

On Lupinus humicola; Willow Creek, Albany Co., July 1, 1898, no. 4380.

Ampelomyces quisqualis Ces.

Reported by David Griffiths from northeastern Wyoming; parasitic on species in several genera of Erysibaceae and on Oidium spp. of the Moniliaceae.

Septoria Urticae Desm.

On Urtica sp.; Little Laramie River, Albany Co., July 4, 1897, no. 3342.

LEPTOSTROMATACEAE.

Piggotia Negundinis E. & E.

On Acer Negundo; Sundance Creek, Crook Co., July 6, 1896, no. 2827.

MONILIALES.

MONILIACEAE.

Ramularia Sidalceae E. & E.

On Sidalcea candida; Cummins, Albany Co., July 29, 1895, no. 1∙68: collected but once before, viz; in British Columbia, by Dr. Macoun.

DEMATIACEAE.

Hadrotrichum Lupini E. & E.

On Lupinus humicola; Willow Creek, Albany Co., July 1, 1898, no. 4380 a.

Cladosporium myriosporum E. & D.

On the pods of Pisum sativuns, grown on the Laramie Experiment Farm, Albany Co., Aug. 20, 1896.

CLASS—BASIDIOMYCETES.

USTILAGINALES.

USTILAGINACEAE.

Ustilago bromivora Fisch.

On Bromus spp.: Battle Lake, Carbon Co., Aug. 16, 1897, no. 4179; Nez Perces Creek, Yellowstone National Park, July 29, 1899, no. 6218; Yellowstone Lake, Aug. 23, no. 6621.

Ustilago Caricis DC.

On Carex spp.: Lincoln Gulch, Albany Co., Aug. 12, 1896, no. 2604; Centennial Hills, Albany Co., Aug. 20, 1896, no. 2687; Battle Lake, Carbon Co., Aug. 16, 1897, no. 4178; Snake River, Yellowstone National Park, Aug. 12, 1899, no. 6432.

UREDINALES.

MELAMPSORACEAE.

Chrysomyxa Ledi (A. & S.)

On Dedum glanduiosum; Sylvan Geysers, Yellowstone National Park, July 26, 1899, no. 6176.

Chrysomyxa Pyrolae (DC.) Rostr.

On Pyrola secunda; La Plata Mines, Albany Co., Aug. 24, 1898, no. 5107.

Cronartium asclepiadeum Thesii Berk.

On Comandra pallida; Medicine Bow River, Carbon Co., Aug. 20, 1897, no. 4257.

Melampsora farinosa (Pers.) Schroet.

Very common on Salix spp.: Cummins, Albany Co., July 29. 1895, no. 1520; Centennial Valley, Aug. 25, 1895, no. 1864.

Melampsorella Cerastii (Pers.) Schrtr.

On Cerastium arvense; Green Top, Albany Co., June 29. 1897, no. 3230: cn Alsine Baicalensis; La Plata Mines, Albany Co., Aug. 24, 1898, no. 5102.

Peridermium elatinum A. & S.

On Picea Engelmanni; Battle Lake, Carbon Co., Aug. 18. 1897, no. 4244.

PUCCINIACEAE.

Uromyces bicolor E. & E.

On Allium sp.; Yancey's, Yellowstone National Park, July 17, 1899, no. 5920.

Uromyces Eriogoni Ell & Hark.

On Eriogonum unbellatum; Ferris Mts., Carbon Co., July 23, 1898, no. 4952: on Eriogonum brevicaule; Wallace Creek, Natrona Co., July 30, 1898, no. 5003.

Uromyces Erythronii DC.

On Erythronium grandiflorum: Obsidian Creek, Yellowstone National Park, July 24, 1899, no 6114.

Uromyces Glycyrrhizae Magnus

Fremont and often abundant on Glycyrrhiza lepidota: Pass Creek, Sheridan Co., July 21, 1896, no. 2474; Granger, Sweetwater Co., July 30, 1897, no. 4136; Gardiner River, Yellowstone National Park, July 19, 1899, no. 5971.

Uromyces Fabae (Pers.) De By.

On Vicia sp.; Bitter Creek, Sweetwater Co., July 1897, no. 3527.

Uromyces Junci (Schw.) Tul.

On Junci (Schw.) Laramie, Albany Co., Dec., 1895, no. 1207.

Uromyces oblongisporus E. & E.

On Artemisia tridentata; South Butte, Sweetwater Co., July 13, 1897, no. 3546.

Uromyces Pisi (Pers.) De By.

On Vicia sp.; Evanston, Uinta Co., July 27, 1897, no. 4106.

Uromyces Polygoni (Pers.) Fckl.

On Rumex pauciflorus; Snake River, Yellowstone National Park, Aug. 13, 1899, no. 6438.

Uromyces Rudbeckiae Arthur & Holway.

On Rudbeckia laciniata; Pass Creek, Sheridan Co., July 21, 1896, no. 2476.

Uromyces Solidagonis Sommerf.

On Solidago Canadensis (?); Sundance, Crook Co., July 4, 1896, no. 2192.

Uromyces Sophorae Pk.

On Sophora sericea; Mill Creek, Converse Co., Aug. 12, 1898, no. 5051.

Uromyces Zygadeni Pk.

On Zygadenus venenosus; Willow Creek, Albany Co., May 22, 1897, no. 2924.

Puccinia Adoxae (Hedeo).

On Adoxa Moschatellina; Yancey's, Yellowstone National Park, July 17, 1899, no. 5929.

Puccinia aunulata E. & E.

On Chamaenerion angustifolium; Yancey's Yellowstone National Park, July 17, 1899. no. 5930.

Puccinia Asteris Duby

On Aster conspicuus; Wolf Creek, Canon, Sheridan Co., July 12, 1896, no. 2293: on Aster sp.; Madison Canon, Yellowstone National Park, Aug. 30, 1899, no. 6780.

Puccinia Balsamorrhizae Pk.

On Balsamorrhiza sagittata; Indian Grove Mts., Carbon Co., July 17, 1898, no. 4900.

Puccinia cladophila Pk.

On Ptiloria pauciflora: Garfield Peak, Natrona Co., July 29, 1894, no. 2830; July 31, 1898, no. 5012.

Puccinia conferta Dietel.

On Artemisia tridentata; Sheep Mt., Albany Co., July 3, 1897, no. 3309 a; Seminole Mts., Carbon Co., July 22, 1898, no. 4945; Laramie Hills, Sept. 13, 1899, no. 6906. on Artemisia cana; Poison Spider Creek, Aug. 1, 1898, no. 5021.

Puccinia consimilis E. & E.

On Schoenocrambe linifolia: Granger, Sweetwater Co., June 10, 1898, no. 4621; Cokeville, Uinta Co., June 11, 1898, no. 4661.

Puccinia Caricis (Schum.) Reb.

On Carex filifolia; Pine Bluffs, Laramie Co., May 15, 1897, no. 2896.

Puccinia cornigera E. & E.

On Tetraneuris Torreyana; Freezeout Hills, Carbon Co., July 10, 1898, no. 4852.

Puccinia Epilobii DC.

On Epilobuim paniculatum: Yellowstone National Park; Nez Perces Creek, July 29, 1899, no. 6223; Snake River, Aug. 12, no. 6431.

Puccinia Erigerontis E. & E

On Erigeron caespitosus; Crow Creek, Laramie Co., July 9, 1896. no. 2847; Ferris Mts., Carbon Co., July 23, 1898, no. 4954: on Erigeron microlonchus; Willow Creek, Albany Co., July 1, 1898. no. 4379: on Erigeron Eatoni; Freezeout Hills, Carbon Co., July 10, 1898, no. 4490.

Puccinia Gayophyti Pk.

On Gayophytum ramosissimum: J. M. Bates, Cambria. Converse Co., June 18, 1896, no. 443; Centennial Valley, July 3, 1897. no. 3285: Seminole Mts., Carbon Co., July 22, 1898, no. 4935.

Puccinia gibberulosa Schitr ?

On Cyrtorhyncha ranunculina; Laramie Hills, Albany Co., June 6, 1896, no. 1906.

Puccinia graminis Pers.

On Poa laevigata; Wamsutter, Sweetwater Co., July 10, 1897, no. 3668 a: on Festuca Kingii; Wallace Creek, Natrona Co., July 30, 1898, no 5004.

Puccinia Harknessii Vize.

On Ptiloria sp.; Fort Steele, Carbon Co., June 18, 1898, no. 4827.

Puccinia Helianthi Schw.

On Helianthus sp.; Cambria Canon, Converse Co., July 29, 1896, no. 2542.

Puccinia Heucherae Sz.

On Heuchera parviflora; Laramie Hills, Albany Co., June 16, 1897, no. 3155.

Puccinia Hieracii (Schum.) Mart.

On Crepis intermedia (?); Seminole Mts., Carbon Co., July 22 1898 no. 4940.

Puccinia intermixta Pk.

Rare; on Iva axillaris: Bitter Creek, Sweetwater Co., July 12, 1897, no. 3526; Casper, Natrona Co., Aug. 2, 1898, no. 5022.

Puccinia Lygodesmiae Pk.

On Gymnolomia miltiflora; Centennial Hills, Albany Co., Aug. 20, 1896, no. 2715.

Puccinia Menthae Pers.

On Mentha Canadensis; Laramie River, Albany Co., Sept. 25, 1897, no. 4302.

Puccinia mirabillissima Pk.

On Berberis nana: Laramie Hills, Albany Co., May 21, 1898, no. 4309; Mommoth Hot Springs, Yellowstone National Park, July 1, 1899, no. 5625.

Puccinia Musenii E. & E.

On Musenium tenuifolium; Freezeout Hills, Carbon Co., July 10, 1899, no. 4491.

Puccinia Phragmitis Schum.

On Spartina gracilis; Laramie River, Albany Co., Aug. 31, 1897, no. 4268.

Puccinia rubigo-vera (DC.) E. & E.

On Elymus sp.; Iron Mt., Laramie Co., Aug. 26, 1896, no. 2732.

Puccinia Saxifragae Schlect.

On Saxifraga cernua; La Plata Mines, Albany Co., Aug. 24, 1898, no. 5124.

Puccinia Tanaceti DC.

On Artemisia cana; W. C. Knight, Steamboat Lake, Albany Co., Oct. 28, 1896, no. 2825: on Artemisia tridentata; Laramie Hills, Sept. 14, 1898, no. 4343.

Puccinia Thalictri Chev.

On Thalictrum sp.; Sundance Creek, Crook Co., July 2, 1896, no. 2105: on Thalictrum sp.; Lewis River, Yellowstone National Park, Aug. 9, 1899, no. 6389.

Puccinia variabilis Grev.

On Taraxacum sp.; Centennial Valley, Albany Co., Aug. 17, 1896, no. 2660.

Puccinia Violae (Schum.) DC.

On Viola sp.; Pass Creek, Sheridan Co., July 21, 1896, no. 2489: Battle Lake, Carbon Co., Aug. 16, 1897, no. 4192.

Gymnosporangium clavipes C. & P.

On Juniperus scopulorum; Laramie Hills, Albany Co., May 10, 1896, no. 1886.

Phragmidium fragariastri DC.

On Potentilla sp.; Freezeout Hills, Carbon Co., July 10, 1898, no. 4851.

Phragmidium subcortium Schrank.

Frequent on species of Rosa: Cummins, Albany Co., July 29, 1895, no. 1499; Sundance, Crook Co., July 2, 1896, no. 2100; Sundance Mt., July 3, no. 2163; Yancey's, Yellowstone National Park, July 17, 1899, no. 5946.

Aecidium abundans Pk.

Very common on Symphoricarpos oreophilus; Cummins, Albany Co., July 29, 1895, no. 1498.

Aecidium Allenii Clinton.

On Lepargyraea Canadensis: Yellowstone National Park; Specimen Ridge, July 15, 1899, no. 5884, Snake River, Aug. 12, no. 6430.

Aecidium Aquilegiae Pers.

On Aquilegia caerulea (?): Laramie Peak, Albany Co., Aug. 7, 1895, no. 2831; North Vermillion Creek, Sweetwater Co., July 17, 1897, no. 3558; Lewis River, Yellowstone National Park, Aug. 9, 1899, no. 6390.

Aecidium Asterum Schw.

On aster sp (?); Sundance Mt., Crook Co., July 3, 1896, no. 2176.

Aecidium Clematidis DC.

On Clematis ligusticifolia: Wolf Creek, Sheridan Co., July 12, 1896, no. 2310; Hat Six Falls, Natrona Co., Aug. 7, 1898, no. 5033.

Aecidium Compositarum Mart.

On Helianethus sp.; Centennial Valley, Albany Co., July 3, 1897, no. 3289: on Aster sp (?); North Vermillion Creek, Sweetwater Co., July 17, 1897, no. 3572: on Aster sp.; Yancey's, Yellowstone National Park, July 17, 1899, no. 5921: on Agoseris sp.; Snake River, Aug. 13, no. 6453.

Aecidium Euphorbiae Pers.

On Euphorbia sp.; Uva, Laramie Co., Aug. 26, 1896, no. 2744: on Euphorbia montana; Ferris Mts., Carbon Co., July 24, 1898, no. 4958.

Aecidium Eurotiae E. & E.

On Eurotia lanata; Laramie, Albany Co., June 15, 1897, no. 3149.

Aecidium Glaucis Dozy & Molkenb.

On Glaux maritima; Laramie, Albany Co., June 15, 1897, no. 3150.

Aecidium Grossulariae (Schum) E. & E.

On Ribes sp.: Moorcroft, Crook Co., July 8, 1896, no. 2244.

Aecidium Hpdrophylli Pk.

On Hydrophyllum occidentale; Green Top, Albany Co., June 29, 1897, no. 3231: on Hydrophyllum capitatum; Mammoth Hot Springs, Yellowstone National Park, June 30, 1899, no. 5599.

Aecidium Lysimachiae Schlect.

On Steironema ciliata; Ranchester, Sheridan Co., July 13, 1896, no. 2286.

Aecidium monoicum Pk.

Frequent on Schoenocrambe linifolia; Laramie Hills, Albany Co., May 23, 1894, no. 50.

Aecidium Oenotherae Mont,

On Pachylophus caespitosus; Pole Creek, Laramie Co., no. 133: on Pachylophus montanus; Laramie, Albany Co., May 31, 1899, no. 6831; on Taraxia heterantha; Golden Gate Yellowstone National Park, June 28, 1899, no. 5534.

Aecidium Orobi Pers.

On Lathyrus ochrolucus; Sundance Creek, Crook Co., July 2, 1896, no. 2110.

Aecidium Peckii De Toni.

On Anogra biennis; Madison Canon, Yellowstone National Park, Aug. 29, 1899, no. 6756.

Aecidium Phlogis E. & E.

On Phlox Hoodii glabrata; Pine Ridge, Albany Co., June 7, 1898, no. 4341.

Aecidium Plantaginis Ces.

On Plantago eriopoda; Laramie, Albany Co., June 9, 1897, no. 2947.

Aecidium porosum E. & E.

On Vicia sp.; Bitter Creek, Sweetwater Co., June 17, 1898, no. 4785.

Aecidium pyratum Sch.

"Headwater of Snake River," Yellowstone National Park, Sept. 11, 1872—Coulter.

Aecidium Ranunculacearum DC.

On Oxygraphis Cymbalaria; Laramie, Albany Co., June 18, 1896, no. 1972.

Aecidium Sarcobati Pk.

On Sarcobatus vermiculatus; Little Laramie River, Albany Co., June 25, 1897, no. 3210.

Aecidium Sommerfeldtii Johans.

On Thalictrum sp.: Sheridan, Sheridan Co., July 10, 1896, no. 2270; Head of Pole Creek, Albany Co., June 19, 1897, no. 3193.

Aecidium tuberculatum E & K.

Very abundant on Sidalcea malvaeflora on Miller's Ranch in the Seminole Mts., Carbon Co., July 23, 1898, no. 4946.

Roestelia aurantiaca Pk.?

On Amelanchier alnifolia; Indian Grove Mts., Carbon Co., July 17, 1898, no. 4887.

Uredo Polypodii (Pers.) DC.

On Cystoperis fragilis; La Plata Mines, Albany Co., Aug. 27, 1898, no. 5196.

Uredo ribicola E. & E.

On Ribes sp.; Laramie, Albany Co., Sept. 8, 1898, no. 5805.

EXOBASIDIALES.

EXOBASIDIACEAE.

Exobasidium Vaccinii (Fckl.) Wor.

On Vaccinium caespitosum; Little Goose Creek Hills, Sheridan Co., July 16, 1896, no. 2367; on Vaccinium membranaceum, Teton Mts., Uinta Co., Aug. 16, 1899.

AGARICALES.

THELEPHORACEAE.

Thelephora terrestris Fr.

"Along the Yellowstone," 1872—Coulter.

CLAVARIACEAE.

Clavaria formosa Pers.

Jackson's Lake, Uinta Co., Sept., 1872.—Coulter.

Clavaria sp.

Battle Lake, Aug. 15, 1897, no. 4199.

This genus is abundant, represented in the coniferous woods by at least one excellent edible species.

HYDNACEAE.

Hydnum imbricatum L.

In moist woods; Battle Lake, Carbon Co., Aug. 16, 1897, no. 4197.

POLYPORACEAE.

Merulius lachrymaus (Jacq.) Fr.

In damp cellar; Cheyenne, Laramie Co., Sept. 15, 1895, no. 1873.

Trametes sp.

Little Goose Creek Hills, Sheridan Co., July 16, 1896, no. 2368.

Polyphorus cuniabarinus (Jacq.) Fr.

Medicine Bow Mts., Albany Co., Aug. 12, 1896, no. 2841.

Polyporus leucospongia Cooke.

Sundance Mt., Crook Co., July 7, 1896, no. 2236.

Polyporus officinalis (Vill.) Fr.

Growing on the under side of moist logs of Pseudotsuga Douglasii; B. C. Buffum, Telephone Canon, Albany Co., 1892, no. 2841; also, secured in the same locality in 1897 by Aven Nelson.

BOLETACEAE.

Boletus spp.

Battle Lake, Aug. 16, 1897, no. 4199.

This genus is abundantly represented in forests mountain areas. Manv no doubt edible.

AGARICACEAE.

Agaricus campester L.

In waste grounds and well manured lots. Common and abundant. Frequently collected for food.

Agaricus silvaticus Schaeff.

Less common than the preceding. In open woods, especially where cattle have wintered.

An excellent edible species. Bacon Ranch, June, 1897.

Coprinus atramentarius (Bull.) Fr.

Moist ground along an irrigating ditch; Laramie, Albany Co., Sept. 7, 1897, no. 4280.

LYCOPERDALES.

LYCOPERDACEAE.

Tylostoma fimbriatum Fr.

On river bottoms; Laramie, Albany Co., Sept., 1896, no. 2826.

Lycoperdon gemmatum Batsch.

On rotten logs; Pole Creek, Albany Co., May 30, 1896, no. 2199.

Lycoperdon pyriforme Schaeff.

Battle Lake, Carbon Co., Aug. 17, 1897, no. 4238 (?); "near Yellowstone Lake, Aug. 23," 1872.—Coulter.

NOTE.—THE FERNS and FERN-ALLIES have not been included in this list, since there are in the state only a relatively small number and these were published with notes upon them, by Mr. Elias Nelson, in the January number (1899) of the Fern Bulletin. Those desiring to know what species occur here are referred to that publication.

METEOROLOGICAL REPORT

. . . *FOR THE YEAR* . . .

Beginning January 1 and Ending December 31, 1899.

BY C. B. RIDGAWAY.

Meteorological Report for 1899.

The work of the meteorological department has been a continuation of that of previous years. Observations upon atmospheric conditions and soil temperature at various depths have been taken twice daily, at 7 a. m. and 7 p. m.

The observations have been reported monthly to the United States Weather Bureau at Washington, and to the Wyoming Section at Cheyenne. Weekly climate and crop reports have also been sent to the Cheyenne office.

The latitude of the Station is 41° 18′ 37.09″ North, and the longitude 105° 34′ 53.75″ West from Greenwich. The altitude of the standard barometer is 7,191 feet.

The equipment of the Station for meteorological observations consists of the following: A quadruple register, with two automatic pens for registering the velocity and direction of the wind; a Draper's self-recording thermometer; a standard mercurial barometer; one Richard's self-registering aneroid barometer; a sling psychrometer; six soil thermometers at different depths in the ground; a maximum and a minimum self-registering thermometer; a hook-gauge and evaporation tank; a standard eight-inch rain gauge; a maximum and a minimum self-registering solar radiation thermometer.

Summary.

Highest temperature, 87, June 29, July 25.

Lowest temperature, —40, February 12.

Mean temperature for year, 38.8.

Greatest daily range of temperature, 63, February 12.

Lowest daily range, 5, October 9.

Mean daily range of temperature for year, 24.4.

Mean relative humidity for the year, 57.1.

Lowest relative humidity, 6, September 7.

Highest dew point, 60, September 5.

Lowest dew point, —38, February 6.

Mean dew point for the year, 23.9.

Highest barometer, 23.502, September 25.

Lowest barometer, 22.442, January 31.

Mean barometer for the year, 23.079.

Highest monthly precipitation, 2.01 inches, in July.

Lowest monthly precipitation, .07, in November.

Greatest amount of precipitation during any single storm, .91 in., July 13.

Total precipitation: 1891, 13.92 in.; 1892, 12.73 in.; 1893, 3.84 in.; 1894, 7.63 in.; 1895, 11.15 in.; 1896, 10.75 in.; 1897, 11.91 in.; 1898, 7.63 in.; 1899, 11.84 in.

Mean precipitation for nine years, 10.15 in.

Evaporation, 20.58 inches, from April 22 to October 15.

Greatest monthly evaporation, 4.42, in May.

Mean soil temperatures: 3 in., 43.2; 6 in., 42.7; 12 in., 44.1; 24 in., 43.7; 36 in., 44.1; 72 in., 43.2.

Prevailing direction of the wind, southwest.

Number of clear days during year, 178.

Number of partly cloudy days during year, 142.

Number of cloudy days during year, 45.

Number of days on which .01 or more precipitation fell, 75.

Greatest velocity of wind, 58 miles per hour, May 21.

Total number of miles traveled by wind during the year, 117,284.

Greatest number of miles traveled in one month, 12,787, January.

Least number of miles traveled in one month, 7,245, November.

Average number of miles for each month, 9,773.6.

Greatest number of miles in one day, 744, May 21.

Least number of miles in a day, 97, December 13.

Mean daily distance traveled, 321.3.

Mean hourly distance traveled, 13.3.

TABLE I.*—*Temperature, 1899.*

	JANUARY						FEBRUARY						MARCH					
Date	7 a.m.	7 p.m.	Max.	Min.	Mean	Range	7 a.m.	7 p.m.	Max.	Min.	Mean	Range	7 a.m.	7 p.m.	Max.	Min.	Mean	Range
1	17	27	33	5	19	28	3	7	13	2	7.5	11	27	28	34	27	30.5	**7**
2	29	26	43	15	29	28	13	9	20	5	12.5	15	26	24	37	24	30.5	13
3	23	12	30	13	21.5	17	6	3	16	1	8.5	15	15	9	32	10	21	22
4	10	12	**16**	3	9.5	13	-4	9	6	-13	-3.5	19	14	14	21	7	14,	14
5	10	9	**16**	4	10	**12**	-13	-15	-1	-13	-7	12	4	20	24	0	12	24
6	9	15	20	-2	9	22	**-35**	**-16**	-9	-39	-24	30	25	32	26	17	21.5	9
7	18	21	31	12	21.5	19	13	9	9	-22	-6.5	31	33	36	40	23	31.5	17
8	13	17	32	6	19	26	14	18	24	4	14	20	44	36	51	31	41	20
9	14	29	38	9	23.5	29	10	23	25	11	18	14	37	**39**	**52**	29	40.5	23
10	11	30	**46**	12	29	**34**	26	-12	28	11	19.5	17	20	11	47	20	33.5	27
11	23	24	38	17	27.5	21	-12	-4	**-14**	-36	**-2.5**	12	11	16	20	9	14.5	11
12	16	21	38	16	27	22	-8	22	23	**-40**	8.5	**63**	16	24	25	12	18.5	13
13	10	13	24	7	15.5	17	20	15	21	13	17	**8**	17	28	30	12	21	18
14	18	21	32	10	21	22	11	16	28	1	14.5	27	16	14	37	15	26	22
15	19	26	33	15	24	18	24	25	35	11	23	24	15	31	22	0	11	22
16	**30**	28	36	24	30	**12**	18	17	26	10	18	16	34	36	42	28	35	14
17	21	12	30	14	22	16	10	25	29	5	17	24	23	9	47	20	33.5	27
18	23	26	38	8	23	30	12	25	33	9	21	24	3	28	33	-3	15	36
19	25	22	38	24	**31**	14	**29**	**34**	**43**	**24**	**33.5**	19	28	31	32	24	28	8
20	23	26	38	21	29.5	17	25	19	29	19	24	10	31	32	43	27	35	16
21	29	**36**	43	**25**	34	18	14	15	22	10	16	12	27	21	39	26	32.5	13
22	21	12	21	7	14	14	3	-10	-3	-28	-15.5	25	19	26	25	15	20	10
23	**-1**	13	25	**-3**	11	28	19	24	34	-13	10.5	47	33	**39**	34	26	30	8
24	19	11	25	10	17.5	15	22	20	36	16	26	20	**38**	**39**	45	**35**	40	10
25	22	30	34	6	20	28	0	1	20	-10	5	30	34	20	50	33	**41.5**	17
26	20	28	32	17	24.5	15	-1	14	20	-7	6.5	27	2	**2**	35	2	18.5	33
27	17	25	28	16	22	12	22	21	34	3	18.5	31	**-10**	3	**3**	**-14**	**-5.5**	17
28	11	**0**	15	-2	**6.5**	17	20	32	35	14	24.5	21	16	27	15	-4	**-5.5**	19
29	23	26	29	-2	13.5	31							29	28	32	24	28	8
30	22	20	25	19	22	6							17	8	27	16	21.5	11
31	20	26	31	**-3**	14	**34**							-5	23	28	-9	9.5	**37**
Sum..	564	654	958	323	640	635	261	346	582	-52	265	624	639	734	1038	482	760	556
Mean	18.2	21.1	30.9	10.4	20.6	20.5	9.3	12.3	20.8	-1.8	9.5	22.3	20.6	23.7	33.5	15.5	24.5	18

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*In all the tables figures printed in bold-faced type give the highest or lowest readings for each month.

TABLE I (Continued).—*Temperature, 1899.*

	APRIL						MAY						JUNE					
Date	7 a.m.	7 p.m.	Max.	Min.	Mean	Range	7 a.m.	7p.m.	Max.	Min.	Mean	Range	7 a.m.	7 p.m.	Max.	Min.	Mean	Range
1	24	32	**28**	18	23	10	42	35	45	30	37.5	15	52	57	64	30	51.5	25
2	30	28	40	24	32	16	29	**27**	54	27	40.5	27	44	**42**	55	39	47	16
3	24	30	40	21	30.5	19	**25**	30	**35**	**18**	**26.5**	17	43	48	51	40	45.5	**11**
4	36	36	38	27	32.5	11	34	39	36	26	31	**10**	44	46	51	40	45.5	**11**
5	25	**24**	46	24	35	22	36	46	51	26	38.5	25	52	55	66	40	53	26
6	**22**	35	31	**12**	**21.5**	19	35	41	56	26	41	30	40	44	**49**	36	**42.5**	13
7	26	31	42	24	33	18	37	40	59	34	46.5	25	46	51	64	30	47	34
8	29	41	39	20	29.5	19	34	49	49	26	37.5	23	49	49	59	38	48.5	21
9	43	45	50	31	40.5	19	48	46	61	36	48.5	25	46	57	64	37	50.5	27
10	46	46	61	36	48.5	25	42	53	53	29	41	24	55	64	65	39	52	26
11	44	48	57	38	47.5	19	52	58	60	40	50	20	59	67	73	51	62	22
12	46	46	56	36	46	20	41	46	69	40	54.5	29	47	53	60	44	52	16
13	41	41	63	38	50.5	25	49	60	56	35	45.6	21	**36**	47	53	35	44	18
14	38	43	51	28	39.5	23	45	55	**72**	45	**58.5**	27	40	56	60	**29**	44.5	31
15	31	45	55	21	38	34	55	54	71	**46**	**58.5**	25	49	58	64	36	50	28
16	**48**	50	53	35	44	18	40	41	58	30	44	28	54	65	72	40	56	32
17	27	36	64	23	43.5	41	41	53	56	28	42	28	60	73	81	46	63.5	35
18	41	45	44	24	34	20	48	57	60	29	44.5	31	58	72	80	49	64.5	31
19	28	26	61	24	42.5	**37**	52	43	67	37	52	30	**67**	65	70	49	59.5	21
20	27	34	39	23	31	16	37	38	65	38	51.5	27	66	61	78	**53**	65.5	25
21	31	49	41	22	31.5	19	35	39	44	28	36	16	52	64	78	44	61	34
22	44	52	59	28	43.5	31	30	45	50	30	40	20	51	50	63	33	48	30
23	45	**57**	**65**	30	47.5	35	47	57	56	32	44	24	58	57	75	45	60	30
24	46	49	64	**39**	**51.5**	25	50	59	59	33	46	26	57	56	76	37	56.5	39
25	45	55	59	31	45	28	**56**	**61**	62	44	53	18	59	69	80	43	61.5	37
26	41	41	63	33	48	30	46	53	69	35	52	34	53	63	70	49	59.5	21
27	37	36	53	25	39	28	44	44	64	33	48.5	31	60	67	79	44	61.5	35
28	29	27	50	23	36.5	27	44	50	61	33	47	28	59	67	82	49	65.5	33
29	28	28	32	25	28.5	**7**	51	60	57	31	44	26	65	**75**	**87**	47	67	**40**
30	32	37	42	29	35.5	13	46	48	66	32	49	**34**	66	73	86	49	**67.5**	37
							45	55	64	28	41	26						
Sum	1054	1193	1488	812	1140	674	1325	1482	1775	1045	1410	730	1587	1771	2065	1250	1652.5	805
Mean	35.1	39.8	49.5	27.6	38.3	22.4	42.7	47.8	57.3	33.7	45.5	23.3	52.9	59	68.5	41.6	55.8	26.8

TABLE I (Continued).—*Temperature*, 1899.

	JULY						AUGUST						SEPTEMBER					
Date	7 a.m.	7 p.m.	Max.	Min.	Mean	Range	7 a m.	7 p.m.	Max.	Min.	Mean	Range	7 a.m	7 p.m.	Max.	Min.	Mean	Range
1	59	55	72	**40**	56	32	62	56	80	43	61	35	58	**67**	82	49	**65**	33
2	58	54	72	47	59.5	25	57	66	78	53	65	25	64	60	78	50	64	28
3	55	52	71	49	60	22	56	55	66	**54**	60	12	58	59	83	44	64	38
4	60	64	79	44	61.5	35	56	54	**63**	53	58	**10**	51	65	82	40	61	42
5	61	65	81	46	63.5	35	59	58	74	47	60	27	58	**67**	**85**	**56**	70	29
6	62	56	78	47	62.5	31	58	57	74	44	61	32	**66**	65	79	42	60	37
7	57	62	73	45	59	28	59	61	71	49	60	22	54	54	67	45	56	22
8	63	67	84	50	67	34	56	64	75	49	62	26	47	50	59	41	50	18
9	64	66	80	45	62.5	35	56	59	75	45	59	32	45	50	71	35	63	36
10	62	65	85	49	67	36	55	65	76	42	59	34	41	59	77	**29**	53	48
11	58	61	78	48	63	30	59	67	77	43	60	34	52	64	80	44	62	36
12	64	63	73	51	62	22	58	62	72	46	59	26	49	61	81	39	60	42
13	63	57	72	47	59.5	25	51	60	75	44	59	31	51	48	76	41	58	35
14	54	56	71	49	60	22	60	69	80	47	64	33	48	53	71	41	56	30
15	53	**51**	69	42	55.5	27	62	65	**83**	51	67	32	44	**45**	57	43	50	**14**
16	54	59	**64**	46	**55**	**18**	61	**53**	76	**54**	65	22	41	46	**55**	39	**47**	16
17	55	62	74	45	59.5	29	55	63	74	46	60	28	44	54	65	35	50	30
18	57	63	72	49	60.5	23	54	61	77	41	59	36	40	54	66	33	50	33
19	59	**71**	79	49	64	30	55	60	68	50	59	18	38	51	64	31	**47**	33
20	**68**	70	81	45	63	**36**	51	66	76	**39**	58	37	42	57	69	32	50	37
21	64	68	85	49	67	**36**	64	68	81	47	64	34	48	57	74	35	54	39
22	65	67	86	**52**	**69**	34	**47**	64	75	42	58	33	39	56	73	31	52	42
23	60	69	76	50	63	26	48	57	68	40	**54**	28	42	60	72	31	51	**49**
24	62	70	83	45	64	38	48	63	77	35	56	42	47	52	65	40	52	25
25	66	**71**	**87**	**52**	69.5	35	56	66	80	41	61	39	40	55	69	33	51	36
26	62	54	74	**52**	63	22	57	65	80	40	60	40	42	53	76	32	54	44
27	58	68	77	48	62.5	29	55	67	80	52	56	**49**	51	**45**	68	43	55	25
28	64	52	73	49	61	24	60	**72**	**83**	**54**	**68**	29	**36**	52	75	30	52	45
29	**51**	56	72	48	60	24	**63**	65	81	50	65	31	40	60	75	42	58	33
30	56	65	77	47	62	30	51	56	68	**54**	61	14	51	52				
31	61	**71**	82	47	64.5	35	58	56	78	46	62	32						
Sum .	1755	1930	2380	1472	1926	908	1747	1919	2345	1420	1883	926						
Mean	56.6	62.2	76.8	47.7	62.1	23.3	56.3	61.9	75.2	45.4	60.7	29.9						

TABLE I (Concluded).—*Temperature*, 1899.

	OCTOBER						NOVEMBER						DECEMBER					
Date	7 a.m.	7 p.m.	Max.	Min.	Mean	Range	7 a.m.	7 p.m.	Max.	Min.	Mean	Range	7 a.m.	7 p.m.	Max.	Min.	Mean	Range
1	**58**	**57**	**72**	42	**56**	30	22	31	47	19	33	28	**35**	**41**	**48**	**28**	**38**	20
2	34	35	49	31	40	18	15	36	52	13	28	**39**	23	12	23	11	17	12
3	27	39	53	22	37	31	27	31	50	23	37	27	3	20	27	—3	10	30
4	21	37	58	14	36	44	31	32	51	24	37	27	15	10	25	7	16	18
5	29	41	66	20	43	**46**	33	35	51	29	40	22	15	28	42	10	26	32
6	42	47	**72**	28	50	44	22	31	47	19	33	28	27	15	28	14	21	14
7	40	41	49	31	40	18	30	38	55	21	38	24	16	26	44	6	25	38
8	34	42	59	22	40	37	28	35	56	26	41	30	32	27	45	17	31	28
9	30	29	34	29	32	**5**	38	40	53	23	38	20	22	18	23	16	20	**7**
10	28	34	36	24	30	12	39	36	46	**32**	39	14	8	4	22	12	17	10
11	36	44	55	25	40	30	**41**	38	54	31	42	23	18	26	33	0	16	33
12	34	35	48	33	41	15	32	42	**59**	26	42	33	10	11	20	8	14	12
13	30	32	33	26	30	7	29	30	52	28	40	24	6	—2	17	0	9	17
14	26	37	39	22	30	17	33	35	58	27	**43**	31	13	7	22	—2	10	24
15	23	**26**	**31**	21	26	10	33	40	54	22	38	32	19	26	31	0	15	31
16	20	29	33	13	23	20	35	36	44	**32**	38	12	30	23	31	10	22	21
17	32	28	38	27	32	11	30	30	45	27	36	18	21	21	28	13	18	11
18	38	40	49	25	37	24	19	33	49	18	34	31	11	—9	19	—10	5	29
19	42	45	53	36	44	17	27	33	57	22	39	35	—6	**—11**	15	—13	1	28
20	49	51	58	40	49	18	24	26	43	17	30	26	—16	—9	15	**—21**	**—3**	36
21	34	50	64	33	48	31	26	38	52	16	34	36	**—18**	—7	**14**	—20	**—3**	34
22	44	40	63	**43**	53	20	19	27	**38**	16	27	22	—5	22	30	—17	6	**47**
23	47	37	57	34	46	23	26	**21**	39	22	31	17	21	16	33	7	20	26
24	34	32	34	27	30	7	15	30	42	12	27	30	29	35	41	14	28	27
25	**12**	31	35	**8**	**22**	27	**11**	29	42	11	**26**	31	24	34	44	16	30	28
26	29	30	43	24	34	19	13	23	45	**9**	27	36	23	30	38	18	28	20
27	26	34	47	23	35	24	26	33	48	19	34	29	25	16	21	13	20	14
28	31	37	54	27	40	27	**41**	**44**	50	30	40	20	23	27	38	15	26	23
29	39	36	57	29	43	28	39	34	58	21	39	37	31	27	43	16	30	21
30	39	44	58	29	44	29	28	30	37	27	32	**10**	27	32	40	15	21	25
31	38	32	43	32	37	11							20	21	31	18	25	13
Sum	1046	1172	1540	840	1290	700	832	907	1474	662	1070	792	504	537	932	198	565	724
Mean	33.8	37.0	50.1	27.4	40.8	22.5	27.7	33.2	49.1	22.1	35.7	26.2	16.4	17.3	30.1	6.4	17.2	23.3

TABLE II.—*Per Cent. of Saturation of the Air and Temperature of the Dew Point.*

Date	JANUARY						FEBRUARY						MARCH					
	RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT		
	7 a m.	7 p.m.	Mean	7 a.m	7 p.m.	Mean	7 a.m.	7 p.m.	Mean	7 a.m.	7 p m.	Mean	7 a.m.	7 p m	Mean	7 a.m	7 p.m	Mean
1	54	36	45	6	9	7.5	100	100	100	3	7	5	65	66	65	19	20	19.5
2	48	91	69.5	15	34	24.5	100	78	89	13	5	9	64	100	82	18	24	21
3	87	81	84	21	9	15	100	100	100	6	3	4.5	83	91	87	12	7	9.5
4	24	47	35.5	—14	—1	—7.5	100	100	100	—4	9	2.5	82	82	82	11	11	11
5	60	58	59	1	0	.5	48	100	72	—24	—15	—19.5	74	71	73	-1	14	6.5
6	58	51	54.5	0	3	1.5	42	100	71	—38	-16	-27	75	35	55	20	12	16
7	84	72	78	15	15	15	100	78	89	13	5	9	45	57	51	18	25	21.5
8	81	84	82.5	10	14	12	82	84	83	11	15	13	24	27	25	15	25	20
9	47	78	62.5	1	25	13	100	87	93.5	10	21	15.5	53	39	46	25	20	22.5
10	27	40	33.5	—11	13	1	88	100	94	23	—12	5.5	85	100	92	18	11	15
11	74	100	87	17	24	20.5	100	64	82	—12	—10	11	79	68	73	7	10	8.5
12	83	48	65.5	13	8	10.5	56	73	64.5	—16	16	0	68	51	59	10	12	11
13	60	81	70.5	1	10	5.5	71	83	77	14	12	13	69	47	58	11	14	12.5
14	41	40	40.5	2	7	4.5	79	83	81	7	13	10	100	47	74	16	1	8.5
15	57	76	66.5	9	21	15	74	42	58	19	9	14	83	59	71	12	21	16
16	68	100	84	23	28	25.5	69	69	69	11	11	11	66	66	66	26	27	26.5
17	86	100	93	19	12	15.5	100	87	93.5	10	22	16	100	100	100	23	9	16
18	74	64	69	17	18	17.5	100	63	81.5	12	17	14.5	100	56	78	3	17	10
19	100	100	100	25	22	23.5	66	54	60	21	22	21.5	56	42	49	17	15	16
20	74	76	75	17	21	19	63	57	60	17	9	13	79	60	70	27	23	25
21	67	50	58.5	21	22	21.5	82	83	81.5	11	12	11.5	100	86	93	27	19	23
22	58	100	79	11	12	11.5	100	54	77	3	—18	—7.5	57	76	67	9	21	15
23	100	47	73.5	—2	0	—1	57	63	60	9	16	12.5	90	54	72	31	26	28
24	57	100	78.5	9	11	10	66	100	83	15	20	17.5	75	68	71	32	30	31
25	61	59	60	13	20	16.5	100	100	100	0	1	.5	72	85	78	27	18	22.5
26	100	100	100	20	28	24	100	82	91	-1	11	5	100	100	100	2	2	2
27	84	75	79.5	14	20	17	60	100	80	13	21	17	100	100	100	—10	3	—3.5
28	80	100	90	7	0	3.5	71	90	80.5	14	30	22	83	77	80	13	22	17
29	74	88	81	17	23	20							58	88	73	19	25	22
30	86	100	93	20	20	20							100	100	100	17	8	12
31	85	54	69.5	18	15	16.5							100	73	86	—5	17	6
Sum .	2149	2213	2181	335	459	397	2274	2274	2274	161	236	198	2375	2171	2273	469	509	489
Mean	69.3	71.4	70.3	10.8	14.7	12.7	63.3	63.3	63.3	5.2	7.6	6.4	77	70	73.5	15	16	15.5

TABLE II (Continued).—*Per Cent. of Saturation of the Air and Temperature of the Dew Point.*

Date	APRIL						MAY						JUNE					
	RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT		
	7 a.m.	7 p.m.	Mean	7 a.m.	7 p.m.	Mean	7 a.m.	7 p.m.	Mean	7 a.m.	7 p.m.	Mean	7 a.m.	7 p.m.	Mean	7 a.m.	7 p.m.	Mean
1	87	60	74	22	23	22.5	43	**91**	67	24	32	28	48	34	41	35	32	33.5
2	**100**	**100**	**100**	30	28	29	**100**	65	82	29	19	24	71	**84**	**77.5**	36	38	37
3	87	50	68	22	17	20	63	50	57	17	**17**	**17**	70	61	65.5	35	37	36
4	66	57	62	27	25	26	47	46	46	19	23	21	71	59	65	36	34	35
5	**100**	**100**	**100**	25	24	24.5	57	31	44	25	22	23.	30	50	34.5	30	38	34
6	86	73	79	20	29	24.5	57	77	67	24	35	30	40	71	55.5	**22**	36	29
7	76	59	68	21	21	21	91	84	**88**	35	36	35	66	51	58.5	36	35	35.5
8	89	30	60	28	16	20	82	45	64	30	31	31	67	67	67	39	39	39
9	33	42	38	20	26	23	44	48	46	29	30	30	72	47	50.5	38	39	38.5
10	31	31	31	22	22	22	56	22	39	29	20	24.5	40	20	30	33	**26**	29.5
11	33	93	63	21	46	34	81	23	52	**47**	25	36	32	23	26.5	31	31	31
12	48	31	40	30	22	26	84	53	70	37	32	**34.5**	66	43	54.5	37	33	35
13	63	25	44	31	13	22	50	15	32	33	18	25.5	**100**	38	69	36	**26**	31
14	32	21	**27**	15	12	13.5	**11**	45	28	**—1**	36	17.5	76	38	57	34	33	33.5
15	42	24	33	15	16	15.5	16	**19**	**18**	16	18	**17**	55	32	43.5	35	31	33
16	28	26	**27**	21	21	21	40	37	38	22	20	21	40	27	33.5	32	33	32.5
17	36	20	28	**9**	**6**	**7.5**	42	22	32	23	29	21.5	37	18	27.5	36	30	33
18	37	42	39	20	26	23	44	22	33	29	23	26	44	19	31.5	38	31	34.5
19	36	76	56	10	21	12	29	85	57	25	**39**	32	**29**	33	31	36	38	37
20	88	26	57	25	8	16	83	52	68	33	24	28.5	37	58	47.5	41	**47**	44
21	**25**	30	**27**	11	23	17	73	61	67	29	29	29	39	20	29.5	30	**26**	**28**
22	46	**13**	30	27	9	18	76	59	67	33	33	33	36	62	49	28	38	33
23	42	22	32	28	23	24.5	49	34	42	31	32	31.5	72	47	59.5	**50**	39	**44.5**
24	66	55	61	**36**	**35**	**35.5**	51	20	36	34	23	28.5	61	56	58.5	45	42	43.5
25	64	28	46	34	20	27	33	23	28	30	27	28.5	48	24	36	41	34	37.5
26	63	30	46	31	16	24	48	34	41	30	28	29	53	25	39	38	30	34
27	36	74	55	17	30	23	85	46	60	40	27	33.5	41	23	32	38	31	34.5
28	**100**	**100**	**100**	29	27	28	46	26	36	27	21	24	40	32	36	36	38	37
29	88	**100**	94	25	28	26.5	32	**19**	25	26	22	24	31	**17**	**24**	36	31	33.5
30	**100**	58	79	32	26	29	59	34	46	34	25	29.5	42	18	30	44	20	36.5
31							42	33	37	26	29	27.5						
Sum	1828	1496	1662	600	659	674	1624	1311	1407	865	816	840.5	1563	1197	1380	1082	1025	1053.5
Mean	61	40	55.4	23	22	22.5	52	42	47	28	26	27	52.1	39.9	46	36	34.1	35.1

TABLE II (Continued) —*Per Cent. of Saturation of the Air and Temperature of the Dew Point.*

Date	JULY						AUGUST						SEPTEMBER					
	RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT		
	7 a.m.	7 p.m.	Mean	7 a.m.	7 p.m.	Mean	7 a.m.	7 p.m	Mean	7 a.m.	7 p.m.	Mean	7 a.m.	7 p.m.	Mean	7 a.m.	7 p m	Mean
1	73	65	69	51	44	47.5	43	82	63	41	51	46	57	46	52	44	41	43
2	62	76	69	46	47	46.5	72	34	53	49	39	44	45	50	47	44	44	44
3	65	75	70	44	45	44.5	71	**94**	82	48	53	50	62	26	44	**46**	37	41.5
4	41	40	40.5	38	41	39.5	**88**	82	**85**	**53**	51	**52**	51	56	54	35	51	43
5	54	33	43.5	46	38	42	61	53	57	45	42	43	29	76	52	31	**60**	**45**.5
6	47	82	64.5	43	51	47	57	72	65	44	49	47	27	14	**21**	27	27	27
7	67	69	68	47	**53**	50	63	42	52	47	39	43	65	**6**	36	43	**9**	26
8	60	29	44.5	50	36	43	60	36	48	43	39	41	79	81	80	42	45	43.5
9	40	31	35.5	41	37	39	46	48	47	37	41	39	**100**	34	67	40	26	33
10	51	45	48	45	45	45	40	28	34	36	35	35	40	48	44	24	42	33
11	62	63	62.5	46	49	47.5	38	30	34	33	36	35	26	17	22	25	23	24
12	65	60	62.5	53	50	**51.5**	40	43	41	35	41	38	50	32	41	33	35	34
13	60	72	66	50	49	49.5	52	49	51	41	47	44	30	**100**	65	34	48	41
14	82	66	74	49	43	46	49	19	34	42	28	35	73	53	63	41	38	39.5
15	76	**93**	**84.5**	46	49	47.5	47	51	49	43	45	44	**100**	79	**90**	44	40	42
16	65	63	64	43	47	45	58	76	67	47	46	46	84	72	78	37	38	37.5
17	77	64	70.5	49	51	50	65	39	52	44	40	42	64	34	49	24	39	32
18	83	56	69.5	52	49	50.5	60	74	67	42	**53**	48	84	43	63	35	35	35
19	73	23	48	51	35	43	40	22	31	33	25	29	83	35	59	34	28	31
20	30	29	29.5	38	38	38	42	17	30	31	24	28	62	15	39	31	20	25.5
21	40	33	36.5	41	40	40.5	**23**	22	22	29	28	28	31	24	27	25	26	25.5
22	45	39	42	45	43	44	33	23	28	23	29	26	60	22	41	29	25	27
23	35	18	26.5	48	28	38	34	26	30	25	27	25	49	68	58	27	49	38
24	**89**	**17**	53	**59**	**27**	43	38	**16**	27	27	**21**	24	30	42	36	23	32	27.5
25	**25**	26	**25**.5	**32**	38	35	22	**16**	**11**	**22**	23	**22**	69	35	52	31	32	31.5
26	34	88	61	36	50	43	30	18	24	29	25	27	56	23	40	29	23	26
27	78	30	54	52	38	45	49	29	39	36	36	36	30	50	40	26	29	27.5
28	45	81	63	44	46	45	26	26	26	28	38	33	66	23	44	27	21	24
29	81	60	70.5	46	43	44.5	44	45	44	42	44	43	38	11	25	**22**	19	**20**.5
30	60	41	50.5	43	43	43	72	77	75	49	49	49	**24**	21	22	23	21	22
31	46	16	31	42	**27**	**34.5**	62	38	50	46	33	40						
Sum	1811	1583	1697	1416	1320	1368	1525	1327	1426	1191	1176	1183	1661	1236	1448	986	994	990
Mean	58.4	51.1	54.7	45.6	42.6	44.1	49.2	42.7	46.1	38.4	37.9	38.1	55.3	41.5	48	32.9	33.1	33

TABLE II (Concluded).—*Per Cent. of Saturation of the Air and Temperature of the Dew Point.*

Date	OCTOBER						NOVEMBER						DECEMBER					
	RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT			RELATIVE HUMIDITY			DEW POINT		
	7 a.m.	7 p.m.	Mean	7 a.m.	7 p.m	Mean	7 a.m.	7 p.m.	Mean	7 a.m.	7 p.m.	Mean	7 a.m.	7 p.m.	Mean	7 a.m.	7 p.m.	Mean
1	29	24	26.5	31	26	28.5	73	40	56.5	16	15	15.5	47	**34**	**40.5**	21	20	20.5
2	**100**	47	73.5	**34**	21	27.5	83	57	70	12	25	18.5	**100**	81	90.5	23	9	16
3	77	45	61	22	23	22.5	77	80	78.5	22	27	24.5	73	43	58	−1	6	2.5
4	86	18	52	19	**7**	**13**	**100**	51	75.5	31	20	25.5	66	58	62	8	1	4.5
5	47	30	38.5	15	11	**13**	53	56	54.5	20	24	22	32	56	44	−3	17	7
6	**22**	**13**	**22.5**	15	12	13.5	73	**21**	47	16	**6**	11	65	66	65.5	19	8	13.5
7	38	62	50	22	31	26.5	58	36	47	20	19	19.5	67	53	60	10	15	12.5
8	73	63	68	27	32	29.5	66	30	48	21	14	15.5	**24**	65	44.5	8	19	13.5
9	**100**	**100**	**100**	30	29	29.5	28	54	41	15	27	21	**100**	**100**	**100**	22	18	20
10	77	**100**	88.5	23	**34**	28.5	**100**	70	**85**	**39**	**30**	**34.5**	**100**	74	87	8	0	4
11	82	64	73	32	**34**	**33**	55	59	57	28	28	28	69	88	79.5	11	23	17
12	91	73	82	32	29	30.5	60	42	46	23	24	23.5	58	60	59	1	2	1.5
13	**100**	**100**	**100**	30	32	31	57	38	47.5	19	13	16	76	66	71	1	−8	−3.5
14	53	67	60	15	28	21.5	**26**	22	**24**	11	10	10.5	45	53	49	0	−3	−1.5
15	48	88	68	**10**	34	17	44	46	45	18	25	21.5	41	76	58.5	4	21	12.5
16	85	57	71	18	19	18.5	54	48	51	24	22	23	89	**100**	94.5	27	23	25
17	70	77	73.5	25	23	24	68	58	63	23	20	21.5	**100**	86	93	21	19	20
18	68	69	68.5	29	31	30	56	35	45.5	10	14	12	80	52	66	7	−17	−5
19	56	46	51	29	28	28.5	43	26	34.5	12	11	11.5	58	48	53	−13	**−21**	−17
20	28	24	26	23	23	23	62	65	63.5	16	18	17	32	52	42	−28	−17	−22.5
21	65	27	46	26	24	25	76	52	64	21	24	22.5	26	56	41	**−33**	−15	**−24**
22	38	69	53.5	24	31	27.5	70	54	62	13	16	14.5	75	**34**	54.5	9	4	−2.5
23	24	50	37	20	24	22	63	**73**	68	18	15	16.5	72	51	61.5	15	5	10
24	54	**100**	77	22	32	27	83	58	70.5	12	20	16	57	66	62.5	19	**26**	**22.5**
25	**100**	**100**	**100**	12	31	21.5	80	56	68	**8**	19	13.5	50	45	47.5	12	19	15.5
26	78	68	73	25	23	24	81	48	50.5	10	10	**10**	74	79	76.5	17	**26**	21.5
27	76	65	71.5	21	26	23.5	64	72	68	18	26	22	51	67	59	14	10	12
28	69	58	63.5	24	26	25	48	44	46	26	27	26.5	48	77	62.5	10	22	11
29	45	48	46.5	23	22	27.5	53	45	49	26	19	22.5	50	65	62	21	19	20
30	30	51	40.5	17	29	23	56	38	47	17	13	15	78	51	64.5	**25**	20	**22.5**
31	44	70	57	22	25	23.5							71	58	64.5	14	11	12.5
Sum	1963	1873	1918	717	790	735.3	1910	1474	1692	565	582	573.5	1983	1960	1471.5	251	282	266.5
Mean	63.3	60.4	61.8	23.1	25.5	24.3	63.7	49.1	56.4	18.8	19.4	19.1	63.9	63.2	63.5	8.1	9.1	8.6

TABLE III.—*Weekly Means of Soil Temperatures.*

WEEK ENDING	Air Temp.	DEPTH					
		3 Inches	6 Inches	12 Inches	24 Inches	36 Inches	72 Inches
January 6	17.4	17.7	18.4	22.0	24.6	27.9	35.2
January 13	18.6	19.0	20.0	22.0	23.8	27.0	35.0
January 20	22.8	24.3	23.8	24.8	25.4	27.4	34.0
January 27	20.0	25.9	23.5	25.4	26.5	28.9	34.0
February 3	12.8	23.5	23.6	25.7	27.0	29.0	34.0
February 10	1.9	15.2	16.4	20.9	24.1	28.2	34.0
February 17	12.8	19.0	19.0	21.1	23.9	27.1	33.6
February 24	17.9	26.0	22.6	24.6	25.8	27.4	32.9
March 3	17.0	24.7	24.3	26.0	26.5	28.1	32.5
March 10	26.0	27.0	26.6	27.8	28.2	29.3	32.5
March 17	20.7	26.5	26.5	28.4	29.0	30.0	33.0
March 24	25.3	31.3	30.2	30.7	30.4	31.2	33.0
March 31	15.0	30.2	30.0	31.6	31.4	32.0	33.3
April 7	28.7	32.0	32.3	33.0	32.1	32.5	34.0
April 14	42.6	41.2	41.7	40.4	35.7	35.3	34.0
April 21	37.0	42.0	43.0	43.5	40.9	39.1	35.2
April 28	43.1	48.1	47.2	47.2	44.5	42.2	37.0
May 5	33.4	39.5	39.3	41.1	41.2	42.3	38.7
May 12	44.4	46.1	45.7	45.3	43.1	42.0	39.0
May 19	49.5	51.8	51.0	52.3	47.6	46.0	39.5
May 26	47.3	49.9	49.5	49.7	48.2	47.3	41.5
June 2	48.7	52.8	52.0	52.7	51.0	49.1	43.0
June 9	48.0	50.5	42.6	49.8	49.2	48.9	43.4
June 16	53.5	58.5	57.4	56.4	53.0	51.0	44.0
June 23	61.0	65.2	63.7	62.6	58.8	55.2	45.8
June 30	63.5	67.8	66.3	65.1	61.6	58.5	48.0
July 7	58.0	63.3	63.5	64.4	62.4	60.3	49.7
July 14	61.6	65.5	64.7	65.0	62.5	60.5	51.1
July 21	61.0	64.0	63.4	63.7	61.1	59.7	52.0
July 28	62.7	64.9	67.4	67.1	64.7	62.3	52.0
August 4	58.9	65.1	64.4	65.0	63.1	62.0	53.0
August 11	59.4	63.1	63.4	63.4	61.8	61.0	54.0
August 18	59.4	67.0	65.5	65.3	63.0	61.3	54.0
August 25	58.0	65.9	65.3	65.0	63.0	62.0	54.0
September 1	60.8	67.9	66.1	65.7	63.7	62.0	55.0
September 8	58.5	66.2	65.5	65.7	64.1	62.0	55.1
September 15	50.3	63.0	62.6	63.0	62.0	61.3	55.0
September 22	47.6	59.4	58.3	59.0	58.5	58.7	55.0
September 29	48.0	60.6	59.0	58.7	57.7	57.0	54.0
October 6	40.7	54.0	53.7	55.2	55.3	56.0	53.3
October 13	35.0	43.0	45.0	49.0	50.3	52.3	52.3
October 20	34.7	38.0	37.5	40.8	43.1	47.0	50.7
October 27	34.0	33.3	39.5	42.0	43.0	45.0	49.0
November 3	32.0	39.0	38.0	40.1	40.7	43.3	47.0
November 10	33.0	38.0	37.0	39.0	42.0	42.0	46.1
November 17	34.1	38.0	37.0	39.2	39.3	41.0	45.0
November 24	26.0	34.4	34.1	36.0	37.1	40.2	44.0
December 1	30.5	34.0	33.0	34.8	35.0	38.1	43.0
December 8	19.2	29.8	30.3	33.4	34.5	37.2	41.5
December 15	13.3	26.8	27.0	30.5	32.3	35.0	40.5
December 22	3.3	21.8	23.5	28.0	30.1	34.0	39.9
December 29	25.7	25.7	24.7	27.0	28.5	32.0	39.0
Sums	1934.6	2247.4	2220.0	2296.1	2272.3	2296.1	2245.3
Means	37.2	43.2	42.7	44.1	43.7	44.1	43.2

TABLE IV.—*Atmospheric Pressure.*

Date	JANUARY			FEBRUARY			MARCH			APRIL		
	7 a. m.	7 p. m.	Mean	7 a. m.	7 p. m.	Mean	7 a. m.	7 p. m.	Mean	7 a. m.	7 p. m.	Mean
1	23.024	22.774	22.899	22.588	22.568	22.578	22.732	22.802	22.767	22.956	22.876	22.916
2	22.794	22.734	22.764	22.560	**22.500**	**22.530**	22.808	22.870	22.838	22.842	22.946	22.844
3	**22.634**	22.812	22.723	**22.503**	22.712	22.607	22.882	23.082	22.982	23.130	23.182	23.156
4	22.816	22.910	22.863	22.648	22.714	22.681	23.026	**23.140**	23.083	23.086	22.988	23.037
5	22.886	22.978	22.932	22.748	22.804	22.772	**23.222**	23.126	**23.174**	23.000	23.190	23.095
6	23.038	23.102	23.070	22.784	22.866	22.825	23.128	**23.140**	23.134	23.192	23.142	23.167
7	23.020	22.984	23.002	22.896	22.790	22.843	23.116	23.086	23.101	23.296	**23.330**	**23.313**
8	22.950	22.988	22.969	22.802	22.830	22.816	23.022	23.070	23.046	23.286	23.226	23.256
9	23.026	23.078	23.052	22.874	22.901	22.887	22.892	22.764	22.828	23.164	23.036	23.100
10	22.936	22.880	22.908	22.792	23.000	22.896	22.630	22.924	27.777	22.932	22.930	22.931
11	22.738	22.668	22.703	23.091	**23.228**	23.159	22.898	22.918	22.908	23.030	23.106	23.068
12	22.788	22.944	22.866	**23.226**	23.020	23.123	22.896	22.878	22.887	23.076	22.942	23.009
13	22.982	23.044	23.013	22.938	23.061	22.999	22.782	22.692	22.737	22.926	23.056	22.991
14	23.048	22.974	23.011	23.026	23.068	23.047	22.708	22.967	22.838	23.150	23.218	23.184
15	22.904	22.900	22.902	22.976	22.966	22.971	23.016	22.998	23.007	**23.354**	23.226	23.290
16	22.850	23.080	22.965	22.992	23.032	23.012	22.952	22.898	22.925	23.058	22.794	22.926
17	23.122	**23.200**	23.161	23.076	23.010	23.043	22.712	22.828	22.770	22.876	22.958	22.917
18	23.168	23.162	23.165	23.218	23.182	**23.200**	22.820	22.994	22.907	22.892	**22.784**	22.838
19	23.160	23.138	23.149	23.086	23.020	23.053	22.994	22.886	22.940	22.918	23.142	23.030
20	23.118	23.208	23.163	22.882	22.872	22.877	22.722	22.728	22.725	23.206	23.206	23.206
21	23.218	23.024	23.121	22.768	22.782	22.775	22.700	22.766	22.733	23.250	23.176	23.213
22	22.916	23.128	23.022	22.868	23.112	22.990	22.828	22.940	22.883	23.078	22.978	23.028
23	**23.266**	23.108	**23.187**	22.984	22.892	22.938	22.904	23.000	22.952	23.026	23.034	23.030
24	22.976	23.030	23.003	22.620	22.642	22.631	22.900	22.916	22.903	23.086	23.056	23.071
25	22.868	22.866	22.867	22.614	22.698	22.656	22.864	22.792	22.828	23.076	22.900	22.988
26	22.934	22.814	22.874	22.700	22.760	22.780	22.818	22.900	22.859	22.962	22.864	22.913
27	23.130	22.792	22.961	22.726	22.758	22.742	22.892	22.870	22.881	22.782	22.790	**22.786**
28	22.868	22.928	22.898	22.780	22.714	22.747	22.801	22.798	22.800	**22.728**	22.940	22.834
29	22.816	22.750	22.783				**22.604**	**22.572**	**22.588**	22.942	22.882	22.912
30	**22.634**	22.746	22.690				22.662	22.900	22.781	22.802	22.862	22.832
31	22.700	**22.442**	**22.571**				22.916	22.964	22.940			
Sum. . . .	711.828	711.186	711.257	639.776	640.492	640.134	708.863	710.209	709.536	691.102	691.760	690.931
Mean . . .	22.946	22.942	22.944	22.849	22.874	22.862	22.866	22.909	22.887	23.037	23.025	23.031

TABLE IV (Continued).—*Atmospheric Pressure.*

Date	MAY			JUNE			JULY			AUGUST		
	7 a. m.	7 p. m.	Mean	7 a. m.	7 p. m.	Mean	7 a. m.	7 p. m.	Mean	7 a. m.	7 p. m.	Mean
1	22.822	**22.712**	**22.767**	22.942	22.864	22.903	23.372	23.278	23.325	23.238	23.270	23.254
2	**22.694**	22.854	22.774	22.918	22.870	22.894	23.288	23.240	23.264	23.232	23.268	23.250
3	22.942	23.002	22.972	**22.814**	22.890	22.852	23.234	23.160	23.197	23.278	23.210	23.244
4	23.088	23.078	23.083	22.848	22.866	22.857	23.198	23.152	23.175	23.196	23.186	23.191
5	23.026	23.002	23.014	22.880	**22.800**	**22.840**	23.176	23.176	23.176	23.222	23.224	23.223
6	23.094	23.054	23.074	22.992	23.044	23.018	23.260	23.292	23.276	23.270	23.214	23.242
7	23.158	**23.274**	**23.216**	23.150	23.182	23.166	23.338	23.326	23.332	23.190	23.150	23.170
8	**23.238**	23.100	23.169	23.238	23.260	23.249	23.336	23.314	23.325	23.190	23.160	23.175
9	22.990	23.028	23.009	23.284	23.024	23.154	23.376	23.336	23.356	23.218	23.182	23.200
10	23.180	23.174	23.177	23.218	23.090	23.154	23.378	23.318	23.348	23.160	23.124	23.142
11	23.180	23.030	23.105	23.042	22.898	22.970	23.342	23.278	23.310	23.202	23.170	23.186
12	23.088	23.160	23.124	22.954	22.950	22.952	23.336	23.336	23.336	23.202	23.154	23.178
13	23.030	22.952	22.991	23.008	23.132	23.070	23.374	23.286	23.330	23.220	23.152	23.186
14	23.004	22.942	22.973	23.320	23.310	23.315	23.268	23.222	23.245	23.176	23.132	23.154
15	22.868	22.860	22.864	23.402	23.386	23.394	23.280	23.292	23.286	23.228	23.234	23.231
16	22.992	23.040	23.016	23.178	**23.438**	23.308	23.368	23.360	23.364	23.180	23.106	23.143
17	23.152	23.066	23.109	**23.480**	23.376	**23.428**	**23.432**	**23.370**	**23.401**	23.128	23.066	23.097
18	23.084	23.010	23.047	23.420	23.360	23.390	23.410	23.334	23.372	23.132	23.060	23.096
19	23.028	22.936	22.982	23.318	23.268	23.293	23.300	23.192	23.246	23.088	23.182	23.135
20	22.892	22.836	22.864	23.220	23.074	23.147	23.220	23.162	23.191	23.280	23.136	23.208
21	22.872	23.040	22.956	23.226	23.168	23.197	23.186	23.152	23.169	**23.114**	**23.002**	**23.058**
22	23.108	23.168	23.138	23.000	23.326	23.163	23.208	23.176	23.192	23.168	23.110	23.139
23	23.190	23.166	23.178	23.262	23.228	23.245	23.284	23.278	23.281	23.264	**23.278**	23.271
24	23.190	23.102	23.146	23.258	23.214	23.236	23.334	23.270	23.302	23.292	23.200	23.246
25	23.092	22.982	23.037	23.216	23.090	23.153	23.306	23.270	23.288	23.180	23.112	23.146
26	23.040	22.998	23.019	23.110	23.166	23.138	23.324	23.330	23.327	23.164	23.168	23.166
27	22.996	22.988	22.992	23.358	23.344	23.351	23.284	23.220	23.252	23.230	23.228	23.229
28	23 040	23.072	23.056	23.444	23.352	23.398	23.266	23.260	23.263	**23.330**	23.268	**23.299**
29	23.084	22.944	23.014	23.422	23.346	23.384	23.294	23.260	23.277	23.320	23.232	23.276
30	22.932	22.992	22.962	23.358	23.266	23.312	23.218	23.126	23.172	23.276	23.222	23.249
31	23.064	23.002	23.033				**23.156**	**23.116**	**23.136**	23.230	23.200	23.215
Sum. . . .	714.158	713.564	713.861	695.280	694.572	694.926	722.146	720.882	721.514	719.598	718.400	718.999
Mean . . .	23.037	23.018	23.027	23.176	23.152	23.164	23.297	23.254	23.275	23.212	23.174	23.193

TABLE IV (Concluded).—*Atmospheric Pressure.*

Date	SEPTEMBER			OCTOBER			NOVEMBER			DECEMBER		
	7 a. m.	7 p. m.	Mean	7 a. m.	7 p. m.	Mean	7 a. m.	7 p. m.	Mean	7 a. m.	7 p. m.	Mean
1	23.188	23.212	23.200	23.012	22.932	22.972	**23.412**	**23.384**	**23.398**	23.098	22.988	23.043
2	23.296	23.288	23.292	23.178	23.322	23.250	23.352	23.264	23.308	22.942	23.192	23.067
3	23.212	**23.092**	23.152	23.340	23.368	23.354	23.224	23.218	23.221	23.154	23.102	23.128
4	23.138	23.100	23.119	**23.444**	**23.442**	**23.443**	23.182	23.148	23.165	23.108	23.068	23.088
5	23.162	23.140	23.151	23.412	23.362	23.387	23.170	23.184	23.177	23.022	22.968	22.995
6	23.196	23.224	23.210	23.332	23.202	23.267	23.250	23.276	23.263	22.992	23.164	23.078
7	23.262	23.204	23.233	23.196	23.300	23.248	23.258	23.252	23.255	23.196	23.100	23.148
8	23.292	23.262	23.277	23.162	22.932	23.047	23.268	23.250	23.259	22.936	22.832	22.884
9	23.278	23.288	23.283	22.892	22.876	22.884	23.148	23.128	23.138	**22.806**	22.972	22.889
10	23.436	23.412	23.424	22.818	**22.778**	**22.798**	23.118	23.132	23.125	23.042	23.022	23.032
11	23.448	23.396	23.422	**22.788**	22.848	22.819	23.112	23.138	23.125	22.884	**22.702**	**22.793**
12	23.396	23.234	23.315	22.812	22.804	22.808	23.124	23.084	23.104	22.818	22.902	22.860
13	23.200	23.212	23.206	23.076	23.058	23.067	23.196	23.274	23.235	22.934	23.014	22.974
14	23.104	23.096	23.100	22.942	22.838	22.890	23.246	23.218	23.232	23.150	23.094	23.122
15	**23.052**	23.136	**23.094**	22.818	22.916	22.867	23.092	22.810	22.951	22.996	22.864	22.930
16	23.262	23.292	23.277	23.048	22.972	23.010	**22.814**	22.922	22.868	22.812	22.844	22.828
17	23.278	23.282	23.280	22.872	22.960	22.916	23.042	23.138	23.090	22.828	22.922	22.875
18	23.362	23.328	23.345	22.938	22.996	22.967	23.138	23.082	23.110	23.154	23.334	23.244
19	23.408	23.400	23.404	23.162	23.200	23.181	22.982	22.842	22.912	**23.438**	**23.450**	**23.444**
20	23.382	23.342	23.362	23.226	23.222	23.224	23.004	23.062	23.033	23.400	23.362	23.381
21	23.328	23.262	23.295	23.196	23.124	23.160	22.924	22.814	22.869	23.324	23.268	23.296
22	23.284	23.282	23.283	23.068	23.036	23.052	22.824	22.972	22.898	23.300	23.242	23.271
23	23.366	23.352	23.359	22.932	23.018	22.975	23.176	23.262	23.219	23.240	23.276	23.258
24	23.400	**23.456**	23.428	23.084	23.182	23.133	23.254	23.192	23.223	23.164	23.120	23.142
25	**23.502**	23.418	**23.460**	23.252	23.312	23.282	23.162	23.162	23.162	23.034	22.972	23.003
26	23.382	23.262	23.322	23.284	23.258	23.271	23.156	23.142	23.149	22.900	22.874	22.887
27	23.212	23.306	23.259	23.284	23.286	23.285	23.152	23.158	23.155	22.928	22.982	22.955
28	23.338	23.316	23.327	23.290	23.282	23.286	23.086	23.064	23.075	23.094	23.212	23.153
29	23.300	23.218	23.259	23.246	23.192	23.219	22.912	**22.752**	**22.832**	23.152	23.032	23.092
30	23.180	23.112	23.146	23.156	23.066	23.111	23.022	23.102	23.062	22.934	22.866	22.900
31				23.078	23.326	23.202				22.906	22.992	22.949
Sum . . .	698.644	697.924	698.284	716.338	716.590	716.464	693.800	693.427	693.614	714.686	714.732	714.709
Mean . . .	23.288	23.264	23.276	23.104	23.116	23.110	23.127	23.111	23.119	23.054	23.055	23.055

TABLE V.—*Wind Record.*

JANUARY

Date	DIRECTION FROM			Daily distance in miles	Greatest number miles in one hour of day	Maximum velocity in miles per hour
	7 a. m.	Noon	7 p. m.			
1	sw	sw	w	394	26	36
2	sw	sw	sw	502	39	42
3	sw	sw	w	480	34	**48**
4	w	w	sw	544	**41**	46
5	sw	w	w	530	38	47
6	w	w	w	**670**	40	**48**
7	sw	sw	w	390	38	40
8	s	n	s	270	23	27
9	s	sw	s	208	**13**	18
10	se	sw	sw	265	26	30
11	n	sw	sw	320	28	31
12	sw	w	sw	420	27	33
13	sw	sw	s	370	23	28
14	sw	sw	sw	480	37	43
15	sw	sw	sw	550	32	38
16	w	nw	n	525	30	40
17	ne	e	e	280	32	37
18	sw	sw	sw	240	17	23
19	sw	n	se	420	25	30
20	w	n	sw	261	23	27
21	sw	sw	sw	520	32	39
22	w	nw	nw	608	34	41
23	w	sw	sw	354	35	37
24	sw	sw	sw	440	26	33
25	sw	w	w	481	31	36
26	sw	w	nw	303	29	35
27	nw	w	w	405	27	37
28	ne	nw	s	522	36	43
29	w	w	w	**230**	26	31
30	w	w	w	495	33	36
31	w	sw	w	310	32	40
Sum				12787		
Daily mean				412.5		
Hourly mean				17.2		

FEBRUARY

Date	DIRECTION FROM			Daily distance in miles	Greatest number miles in one hour of day	Maximum velocity in miles per hour
	7 a. m.	Noon	7 p. m.			
1	nw	n	w	300	34	39
2	n	w	se	**112**	12	**14**
3	s	ne	w	252	23	29
4	n	nw	nw	278	16	21
5	n	n	n	274	21	26
6	s	nw	sw	145	14	23
7	sw	w	w	253	18	25
8	nw	nw	n	430	29	37
9	nw	w	w	361	30	33
10	w	w	s	420	29	35
11	n	n	se	250	31	34
12	s	s	se	194	**10**	**14**
13	s	w	e	395	25	33
14	w	sw	nw	253	19	25
15	s	sw	sw	430	32	38
16	sw	nw	nw	340	24	31
17	w	w	w	290	23	29
18	se	n	sw	220	20	27
19	w	sw	sw	490	27	32
20	w	w	w	487	31	37
21	w	w	nw	**590**	39	45
22	nw	nw	s	341	32	41
23	w	sw	s	338	38	46
24	e	n	nw	275	27	35
25	s	s	s	238	25	33
26	s	w	w	130	22	31
27	s	sw	w	540	40	47
28	sw	sw	w	530	**47**	**50**
Sum				9165		
Daily mean				327.3		
Hourly mean				13.7		

TABLE V (Continued).—*Wind Record.*

MARCH							APRIL						
Date	DIRECTION FROM			Daily distance in miles	Greatest number miles in one hour of day	Maximum velocity in miles per hour	Date	DIRECTION FROM			Daily distance in miles	Greatest number miles in one hour of day	Maximum velocity in miles per hour
	7 a. m.	Noon	7 p. m.					7 a. m.	Noon	7 p. m.			
1	sw	w	w	560	34	37	1	ne	se	sw	170	21	28
2	nw	w	sw	368	20	29	2	n	sw	sw	323	23	32
3	n	nw	n	200	18	25	3	nw	sw	sw	256	25	33
4	w	w	w	400	28	33	4	sw	sw	sw	463	35	42
5	nw	w	s	455	32	37	5	n	n	nw	377	27	36
6	s	w	sw	360	30	38	6	s	w	w	282	23	29
7	sw	sw	sw	560	36	40	7	nw	nw	se	479	27	34
8	w	w	se	344	27	33	8	nw	w	s	246	28	30
9	sw	sw	s	360	28	37	9	se	sw	sw	225	18	25
10	ne	nw	nw	456	30	38	10	sw	sw	w	413	28	34
11	nw	nw	w	545	33	37	11	sw	w	s	447	30	35
12	sw	sw	sw	442	33	39	12	sw	sw	sw	413	28	37
13	s	s	se	346	22	25	13	w	w	w	453	28	31
14	ne	w	n	330	19	24	14	s	nw	w	434	32	37
15	e	sw	sw	365	30	36	15	s	nw	se	234	19	25
16	s	sw	sw	350	29	32	16	se	sw	sw	341	33	38
17	e	e	nw	258	25	31	17	w	w	w	743	38	43
18	ne	se	sw	150	17	25	18	s	sw	nw	380	25	29
19	sw	sw	sw	430	28	37	19	w	w	nw	635	33	37
20	s	sw	sw	433	26	28	20	nw	nw	s	623	37	45
21	sw	w	w	380	19	23	21	s	nw	e	298	24	31
22	w	w	sw	610	31	37	22	sw	s	se	225	11	25
23	sw	w	sw	400	34	38	23	s	sw	e	348	27	33
24	sw	w	w	420	30	36	24	n	n	se	393	32	36
25	sw	e	e	490	37	43	25	sw	e	se	359	34	39
26	e	e	e	620	32	39	26	n	w	w	378	31	39
27	e	e	nw	260	24	31	27	w	w	nw	371	41	47
28	w	w	sw	330	25	30	28	nw	nw	s	377	30	35
29	w	e	s	370	27	35	29	se	se	se	394	29	33
30	nw	nw	ne	330	24	32	30	e	nw	w	413	26	32
31	nw	n	ne	180	17	24							
Sum				12111			Sum				11493		
Daily mean				390.7			Daily mean				383.1		
Hourly mean				16.2			Hourly mean				15.9		

TABLE V (Continued)—*Wind Record.*

MAY

Date	DIRECTION FROM			Daily distance in miles	Greatest number miles in one hour of day	Maximum velocity in miles per hour
	7 a. m.	Noon	7 p. m.			
1	se	se	n	385	34	37
2	nw	nw	nw	354	24	32
3	nw	w	w	666	39	45
4	sw	sw	se	447	28	35
5	s	w	nw	294	19	27
6	s	se	s	204	20	29
7	n	ne	se	267	28	34
8	s	sw	sw	183	17	25
9	sw	w	w	258	19	27
10	sw	w	w	321	18	27
11	sw	w	w	457	29	36
12	nw	n	se	463	27	32
13	s	sw	sw	443	42	47
14	s	sw	se	461	34	39
15	se	sw	sw	538	35	44
16	n	se	w	454	37	45
17	s	sw	ne	322	40	47
18	ne	se	s	381	27	34
19	e	se	se	227	18	23
20	nw	nw	w	358	34	41
21	sw	sw	ne	744	47	58
22	se	w	nw	313	32	44
23	s	w	s	283	20	25
24	se	sw	sw	174	11	23
25	se	sw	s	309	34	42
26	n	sw	w	369	36	50
27	s	sw	w	278	24	26
28	w	w	w	429	33	42
29	s	sw	se	311	25	30
30	w	w	w	405	34	37
31	se	w	se	352	37	45
Sum				11481		
Daily mean.				370.3		
Hourly mean.				15.4		

JUNE

Date	DIRECTION FROM			Daily distance in miles	Greatest number miles in one hour of day	Maximum velocity in miles per hour
	7 a. m.	Noon	7 p. m.			
1	se	se	w	401	30	38
2	n	n	sw	326	26	31
3	sw	sw	w	336	24	29
4	w	w	nw	378	22	28
5	w	sw	se	474	35	40
6	w	n	s	460	33	40
7	s	sw	sw	222	18	24
8	e	ne	ne	334	23	32
9	s	ne	ne	285	21	25
10	sw	w	w	244	20	26
11	sw	sw	sw	482	29	33
12	nw	nw	n	417	29	35
13	n	nw	nw	278	20	24
14	n	ne	ne	300	28	30
15	n	n	n	165	9	13
16	se	nw	w	233	20	25
17	se	nw	nw	234	11	15
18	se	nw	nw	244	17	23
19	se	nw	sw	257	20	27
20	s	sw	se	361	25	30
21	sw	w	ne	342	24	28
22	se	ne	e	278	27	34
23	se	nw	nw	462	29	35
24	sw	se	sw	314	34	37
25	sw	se	sw	330	26	38
26	sw	sw	sw	351	21	25
27	sw	w	se	249	16	22
28	e	nw	e	264	17	19
29	w	w	sw	247	24	27
30	s	w	nw	257	16	24
Sum				9523		
Daily mean.				317.5		
Hourly mean.				13.2		

TABLE V (Continued).—*Wind Record,*

JULY							AUGUST						
Date	DIRECTION FROM			Daily distance in miles	Greatest number miles in one hour of day	Maximum velocity in miles per hour	Date	DIRECTION FROM			Daily distance in miles	Greatest number miles in one hour of day	Maximum velocity in miles per hour
	7 a. m.	Noon	7 p. m.					7 a. m.	Noon	7 p. m.			
1	e	e	se	**471**	33	27	1	se	se	sw	414	**35**	**40**
2	e	nw	se	210	27	32	2	sw	nw	nw	205	**11**	17
3	e	nw	sw	400	20	34	3	e	se	ne	192	16	20
4	se	ne	sw	322	31	**40**	4	se	ne	s	**117**	**11**	**14**
5	se	w	nw	343	22	27	5	s	w	sw	272	19	23
6	se	ne	e	274	**29**	35	6	s	se	ne	212	20	24
7	e	e	e	313	**29**	36	7	sw	sw	sw	327	29	35
8	s	nw	e	406	26	30	8	s	sw	w	276	18	25
9	e	se	e	278	24	29	9	sw	sw	sw	285	22	28
10	w	se	se	212	28	33	10	se	w	w	294	23	27
11	se	nw	w	**164**	19	25	11	se	se	s	310	16	21
12	n	w	nw	192	22	26	12	sw	sw	sw	290	20	27
13	e	se	e	216	18	27	13	se	e	s	168	14	20
14	e	ne	nw	172	30	36	14	s	sw	se	461	28	34
15	s	ne	ne	190	24	29	15	s	sw	sw	382	18	**40**
16	e	e	se	152	**11**	**14**	16	sw	sw	s	263	24	36
17	s	nw	se	219	22	26	17	sw	sw	s	234	19	26
18	ne	ne	ne	194	19	23	18	se	sw	s	325	29	33
19	s	nw	ne	186	13	17	19	w	w	w	406	30	35
20	s	ne	se	166	18	22	20	e	se	ne	287	17	25
21	s	nw	sw	279	17	24	21	sw	sw	sw	**503**	32	37
22	ne	se	se	286	21	25	22	sw	sw	sw	370	25	34
23	ne	n	nw	216	20	26	23	se	w	w	379	21	26
24	e	w	w	288	22	27	24	s	w	w	218	14	21
25	e	nw	nw	206	18	23	25	e	sw	sw	296	22	28
26	se	se	nw	422	27	32	26	se	sw	sw	287	20	25
27	se	se	nw	236	32	40	27	ne	w	w	216	19	24
28	s	sw	ne	273	31	36	28	w	w	ne	241	17	23
29	se	s	sw	234	23	25	29	w	nw	e	279	20	24
30	s	se	sw	359	22	28	30	e	nw	se	195	21	26
31	sw	sw	w	341	23	30	31	se	nw	nw	177	16	22
Sum				8220			Sum				8885		
Daily mean				265.1			Daily mean				286.6		
Hourly mean				11			Hourly mean				11.9		

TABLE V (Continued).—*Wind Record.*

SEPTEMBER

Date	Direction from			Daily distance in miles	Greatest number miles in one hour of day	Maximum velocity in miles per hour
	7 a. m.	Noon	7 p. m.			
1	s	s	s	295	24	27
2	se	se	se	280	23	30
3	s	s	s	401	28	32
4	se	sw	s	232	20	27
5	nw	s	s	327	27	34
6	e	sw	e	226	22	26
7	e	s	s	442	26	32
8	se	se	se	**446**	29	34
9	s	nw	nw	258	21	26
10	s	nw	sw	**127**	15	15
11	se	nw	n	191	15	19
12	sw	se	se	255	21	27
13	se	w	sw	343	**35**	**46**
14	e	e	se	234	23	26
15	sw	nw	n	312	21	25
16	ne	s	se	214	19	22
17	se	nw	n	285	20	25
18	s	nw	ne	304	24	30
19	s	se	e	139	13	16
20	se	sw	n	276	23	25
21	se	w	nw	262	22	26
22	se	nw	se	157	16	22
23	s	nw	w	200	17	23
24	se	nw	n	286	24	29
25	se	nw	e	148	**8**	**12**
26	se	nw	nw	217	16	23
27	s	nw	nw	304	34	37
28	se	nw	ne	223	20	24
29	e	nw	w	194	12	17
30	s	sw	se	326	22	26
Sum				7913		
Daily mean				263.7		
Hourly mean				10.9		

OCTOBER

Date	Direction from			Daily distance in miles	Greatest number miles in one hour of day	Maximum velocity in miles per hour
	7 a. m.	Noon	7 p. m.			
1	s	s	sw	455	**45**	**50**
2	s	w	e	258	19	24
3	e	nw	ne	236	20	24
4	s	w	n	167	21	26
5	s	nw	nw	131	**9**	**13**
6	se	nw	nw	198	19	25
7	n	ne	ne	315	15	20
8	s	w	sw	270	23	28
9	nw	n	nw	342	29	35
10	se	s	se	249	23	25
11	se	sw	sw	**663**	40	44
12	nw	sw	w	382	31	36
13	n	ne	se	221	17	24
14	e	se	e	580	40	48
15	nw	n	nw	328	22	30
16	w	w	sw	404	29	35
17	w	sw	nw	432	20	24
18	se	sw	w	406	27	36
19	sw	sw	s	358	20	25
20	sw	se	e	472	35	40
21	e	s	se	237	23	27
22	s	sw	s	339	24	30
23	se	w	w	326	26	32
24	ne	n	ne	256	18	25
25	ne	e	e	**125**	12	15
26	s	sw	w	250	14	21
27	se	w	e	167	15	20
28	se	sw	e	174	11	16
29	s	sw	sw	200	16	29
30	s	w	ne	229	14	16
31	ne	ne	ne	431	30	36
Sum				9601		
Daily mean				309.7		
Hourly mean				12.9		

TABLE V (Concluded).—*Wind Record.*

NOVEMBER

Date	Direction from			Daily distance in miles	Greatest number miles in one hour of day	Maximum velocity in miles per hour
	7 a. m.	Noon	7 p. m.			
1	e	w	se	133	14	18
2	s	w	e	184	12	15
3	e	nw	se	136	**10**	**12**
4	e	w	s	206	14	20
5	se	sw	nw	310	21	25
6	e	nw	w	208	18	23
7	se	nw	w	209	20	24
8	s	sw	s	203	21	25
9	se	sw	sw	326	29	35
10	s	sw	ne	187	12	20
11	sw	w	s	233	20	26
12	e	w	se	219	22	30
13	n	w	se	200	15	21
14	se	w	se	285	23	29
15	se	se	sw	274	31	38
16	w	w	sw	544	28	36
17	sw	w	n	252	16	19
18	s	nw	e	223	18	23
19	e	se	n	227	12	16
20	n	n	ne	177	13	18
21	se	nw	e	290	23	27
22	ne	n	n	158	17	24
23	n	nw	nw	122	**10**	13
24	se	nw	n	**117**	11	**12**
25	s	nw	n	126	16	21
26	se	se	e	124	**10**	12
27	s	w	sw	258	15	19
28	w	w	w	467	32	36
29	se	w	w	501	**43**	**56**
30	nw	w	sw	**646**	33	38
Sum				7245		
Daily mean.				241.5		
Hourly mean.				10		

DECEMBER

Date	Direction from			Daily distance in miles	Greatest number miles in one hour of day	Maximum velocity in miles per hour
	7 a. m.	Noon	7 p. m.			
1	w	w	w	**576**	**34**	**39**
2	nw	nw	nw	553	27	35
3	se	nw	s	275	23	27
4	n	n	e	198	**8**	12
5	se	sw	s	212	17	23
6	w	nw	s	416	23	29
7	se	w	s	294	21	25
8	w	sw	n	281	25	30
9	ne	n	nw	395	25	31
10	se	se	sw	147	15	20
11	s	sw	w	323	21	27
12	w	w	sw	419	**34**	37
13	se	w	e	**97**	**8**	**12**
14	w	w	se	282	17	22
15	sw	sw	se	270	24	30
16	sw	nw	n	350	20	28
17	ne	n	n	193	14	20
18	n	s	s	164	18	23
19	se	s	se	222	16	19
20	se	s	se	139	15	20
21	se	nw	se	146	9	13
22	e	se	se	202	11	14
23	s	s	se	200	13	18
24	sw	sw	sw	367	30	33
25	sw	s	s	282	29	35
26	s	sw	w	425	33	37
27	s	s	ne	244	21	25
28	sw	s	se	192	13	20
29	s	s	s	220	12	15
30	s	s	s	310	20	24
31	nw	n	w	466	25	32
Sum				8860		
Daily mean.				285.8		
Hourly mean.				11.9		

TABLE VI.—*Precipitation and Evaporation (in inches), Laramie, Wyo.*

MONTH	1891		1892		1893		1894		1895		1896		1897		1898		1899	
	Rainfall	Evaporation	Rainfall	Evaporation	Rainfall	Evaporation	Rainfall	Evaporation	Rainfall	Evaporation	Rainfall	Evaporation	Rainfall	Evaporation	Rainfall	Evaporation	Rainfall	Evaporation
January	.70	...	.01	...	T	...	.03	...	.08	...	.44	...	.39	...	.05	...	.05	...
February	.375	...	.36	...	.11	...	.10	...	.14	...	.17	...	.16	...	.01	...	1.13	...
March	1.50	...	.52	...	.29	†	.29	...	.43	...	.59	...	3.97	...	.40	...	1.11	...
April	.25	...	.19	*	.32	*e*.562	1.51	*f*.906	.87	*g*2.530	3.53	...	.55	*i* 1.80	1.26	*k*3.44	1.75	*m*.87
May	2.92	...	1.16	*c*1.59	.33	4.801	.42	6.060	2.09	7.334	.48	...	1.85	7.43	1.88	4.60	.37	4.42
June	.91	...	3.97	8.23	.54	7.884	.64	7.492	2.12	6.236	.72	7.79	.72	7.73	.90	‡10.33	1.11	3.90
July	1.20	*a*4.424	2.22	9.19	.34	9.352	1.41	6.690	2.71	7.294	1.66	8.34	1.29	7.00	.65	8.37	2.01	2.91
August	1.76	8.590	.14	8.27	1.08	6.586	1.26	6.276	1.17	6.066	.89	6.09	1.11	7.33	1.16	6.93	1.43	3.14
September	1.80	5.040	T	6.10	.39	6.016	1.60	6.436	.18	4.944	1.16	4.84	.32	4.84	T	5.68	.17	4.12
October	.30	3.720	3.96	*d*1.50	.28	2.886	.09	3.306	.74	2.616	.18	*h*2.00	.55	*j*4.38	.48	*l*2.05	1.13	*n*1.22
November	1.095	*b*.926	T	...	.06	...	.05	...	.32	...	.09	...	.33	...	.61	...	.07	...
December	1.11	...	.20	...	.10	...	.23	...	.33	...	...	...	.75	...	.23	...	.61	...
Total	13.92	22.7	12.73	34.88	3.84	38.087	7.63	37.166	11.15	37.020	10.75	29.06	11.99	40.51	7.63	41.40	11.84	20.58

a 22d to 31st
h 1st to 22d
b 1st to 11th
i 24th to 30th
c 24th to 31st
j 1st to 26th
d 1st to 10th
k 15th to 30th
e 24th to 30th
l 1st to 15th
f 26th to 30th
m 22d to 30th
g 17th to 30th
n 1st to 15th

*Evaporation between November 11 and May 24 was 9.69 inches—liable to considerable error.

†From October 1, 1892, to October 1, 1893, evaporation was, apparently, 46.305 inches.

‡An exceptionally dry and windy month.

UNIVERSITY OF WYOMING.
Agricultural College Department.

WYOMING EXPERIMENT STATION,
LARAMIE, WYOMING.

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Some Experiments With Subsoiling.

BY B. C. BUFFUM AND W. H. FAIRFIELD.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyo.

Wyoming Agricultural Experiment Station.

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Some Experiments With Subsoiling.

BY B. C. BUFFUM AND W. H. FAIRFIELD.

The natural requisites for farming are soil, water, air, heat and sunshine. With one exception these natural blessings are sufficiently abundant in the arid west. That exception is water. The greatest question in our agriculture is how to make the most of our limited supply of this life-giving element. Making use of our water supply would be a comparatively simple matter if all the moisture which might be brought to the soil could be held there until plants could make use of it. But water is never still. In seeking its common level, the sea, it runs off the surface of the land, or seeps through the upper layers, escaping from below and that which is retained for a time by the soil is being continually dissipated into the air as invisible vapor. In our dry climate the evaporation is so great that five or ten times as much water as comes to the earth in a year by rain would be lost by this process alone. Any practical plan then of saving as much moisture as possible for the use of crops is of great importance and value.

Tillage consists of stirring the soil and is as old as agriculture. Its effect is somewhat complex. It breaks up the soil admitting air, without which plants can not grow. It loosens the soil so it becomes suitable for planting the seed, as well as for the development of plant roots and for the absorption of water, brought to it by rain or irrigation. It disintegrates the soil particles continually unlocking and making available to the plant new stores of plant food. It destroys weeds. Breaking up the surface forms a blanket which prevents the rapid loss of water by evaporation. Is it enough that we shall cultivate the surface of the earth, or shall we find it profitable to extend tillage deeper into the hitherto undisturbed subsoil?

Subsoiling is stirring the earth below the region of the plow. For convenience we speak of the first eight inches of soil which may be turned over in plowing as the surface soil and all below this as the subsoil. Plowing turns the surface soil bottom side up. Subsoiling does not change the position of that part of the soil, but it breaks up and stirs the ground below the ordinary depth of plowing. This may be effected by a spur or prong attached to the plow which breaks up the soil at the bottom of the furrow, or it may be done with a separate implement to be drawn along through the soil beneath the bottom of the furrow after the plow, to stir the ground to greater depths than can be done with a small attachment to the ordinary plow. This implement is called the subsoil plow and usually consists of a mole or a more or less flat piece of iron pointed at one end and attached to the beam by a strong flat vertical blade. When drawn through the soil in the bottom of the furrow left by the plow this implement can be made to break up and stir the subsoil to a depth of from one to two or more feet.

The advantages claimed for subsoiling are that it makes more room for root development, and enables the plant to extract food and moisture from a greater area, and that by loosening up more of the soil its capacity for absorbing and retaining moisture is increased. By the absorption of greater amounts of moisture in winter and spring it is supposed that subsoiling provides against summer drouth. It is reasonable to suppose that this is what would happen and the many favorable reports on subsoiling from humid and semi-arid regions indicate that loosening the lower layers of soil is a valuable way of conserving moisture for those regions. Before discussing the effects of subsoiling in Wyoming the differences between a truly arid region and one which is only semi-arid should be briefly pointed out. Places where the annual rainfall is less than fifteen inches are generally called arid. The air is dry; the evaporation is great; the rainfall is not sufficient to mature cultivated crops. In the semi-arid region the rainfall is more than fifteen inches and may be enough to mature profitable crops if the moisture can be stored up in the soil and saved until the crop can make use of it. In Wyoming the conditions are truly arid unless it be in the extreme northeastern portion of the state. There is little precipitation during the fall and winter, so very little moisture escapes by running directly off the surface of the land. If, then, subsoiling is not necessary to increase the holding capacity of the soil, and absorb water during time of extra supply, will it save more of the water which may be applied artificially during the growing season and will this and other advantages make it profitable to go to the extra expense of such tillage in our state?

To solve this question we have been experimenting with subsoiling for three years and this bulletin is published to report the results obtained. The experiment was conducted in the same manner on the several experiment farms in the state. Unfortunately the records of the Lander farm were lost in transit, and the publication of this bulletin has been long delayed with the hope they might be found. The soil of the Lander and Sundance farms is almost identical, the altitude of the two places is not far different and while the experiment in subsoiling was only carried out one season at Sundance, a comparison of the results obtained would be highly interesting. The climate of Sundance is semiarid or sub-humid, crops being raised without irrigation, while that of Lander is arid and no crops are raised without irrigation. A comparison of the results at these places would give more trustworthy evidence of the difference in value of subsoiling under such conditions of climate and farm practice.

The experiment was begun in the spring of 1896 and carried out that year at Laramie, Lander, Sheridan, Sundance and Wheatland. In 1897 the cropping was repeated on the same land at Laramie, Lander and Sheridan, and in 1898, at Laramie only.

PLAN OF THE EXPERIMENT.

Following is an outline of the instructions for subsoiling which, with slight modifications for each locality, were furnished the farm superintendents in the spring of 1896—

This experiment is to be carried on alike on each of the farms. Select a suitable acre plat. Plow the land over the whole plat the same and let all other operations such as harrowing, etc., be the same for all parts of the plat. Subsoil thoroughly one-half of the plat. Mark carefully and permanently the line where the subsoiling stops.

Divide the plat into four equal parts so one-half of each fourth is on the subsoiled portion and one-half on the part merely plowed.

Upon the first fourth acre plant oats.

Upon the second fourth acre plant potatoes.

Upon the third fourth acre plant wheat.

Divide the last fourth into two parts and plant beets on the one and corn on the other.

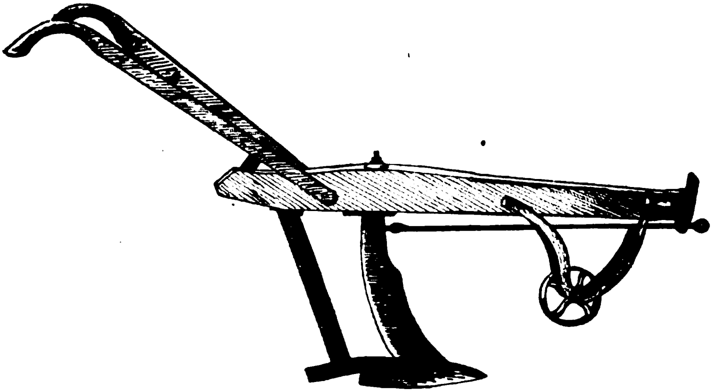
Treat the crops on the plowed and subsoiled land the same throughout the season. Keep careful notes of any variations on the two parts of each plat.

When you harvest each crop cut out a strip six feet wide along the line on which the subsoiling stops, casting out the crop from a strip three feet wide on each side of this line, which part is to be taken no account of in figuring up the yields on subsoiled land or land not subsoiled. This is important as the effects on the ground treated or untreated will reach across the line some distance.

Measure the area in square feet occupied by each crop to be used in figuring up the yields. In the case of rowed crops, allow for the number of rows at their distance apart and take the length of row on treated and untreated land.

This experiment will be repeated upon the same ground for a number of years to determine the effect of subsoiling on soil and crops—.

In 1898 some additional land was subsoiled and on one plat of oats covering one-half acre an accurate measurement was made of the irrigation water used. In 1897, the next year after the land was subsoiled for this experiment, the Physicist made a study of the moisture content of different soils which was published in Bulletin No. 35 of this Station, a resume of which is used in this report.



Results of the Experiments.

Plants of different kinds act very differently when grown on subsoiled land. The effect on a crop of loosening the soil to a depth greater than by ordinary plowing is also very different on different soils and under varying climatic conditions. Our experiments were carried out in widely separated parts of Wyoming and with the more important crops raised in each section. Again there are often accidental variations which throw doubt on the value of an experiment and where possible the work has been repeated more than one season. The conclusions reached have been carefully drawn and we believe the results of these experiments are worthy of consideration by our farmers.

The soil on the station farm at Laramie contains considerable gypsum and lime carbonate, is quite sticky when wet and becomes firmly compacted below the plow. The land selected for this experiment had been cultivated for a number of years. It was plowed about eight inches deep and one-half the plat was subsoiled to a depth of fourteen to sixteen inches in April, 1896. The ground was so hard that four horses were required to pull the subsoil plow and if larger areas were to be treated six horses would be necessary. The land was not again subsoiled but the difference in the yield of crops produced was observed for three seasons. This shows the lasting effects of subsoiling and the return which may be expected from one such treatment, and throws light on the absorption and retension of water through the entire year. The second year there was a slight difference in the depth of the plowing on the two portions of the plat. Where the land had been subsoiled the plow sunk one to three inches deeper than on the plowed portion.

On the other station farms in the state the plowing and subsoiling was done in the same manner as at Laramie. At Sheridan the soil is clay underlaid with true hardpan. It is not known to what extent this hardpan was broken up by the subsoil plow. At Wheatland the soil conditions are much the same as those at Laramie. At Sundance the soil is deep, contains gypsum and much of the subsoil consists of red shale which is not tenaceous but comparatively easy to work.

The average rainfall is nearly ten inches at Laramie; about the same at Wheatland, nearly fourteen inches at Sheridan and twenty inches at Sundance. At Laramie and Wheatland from fifty to sixty percent of the total annual precipitation falls ,in the growing months of May, June, July and August. The greater amount of precipitation at Sundance and the fact that the land was not irrigated undoubtedly accounts for some of the difference noted in the effects of subsoiling between the Sundance and other farms.

Subsoiling for Grain Crops.

Table I. gives the effects of subsoiling on the yields of wheat. Though the difference was not great, the yield from the subsoiled land was less than that from the land only plowed, at Laramie, the year the subsoiling was done. The second and third years there was a slight increase in yield from the subsoiled land. The increase in the yield of straw is greater in proportion than that of grain. This condition would be expected as the increased feeding area of the roots and other conditions favoring rank growth would produce more straw and less grain where the growing season is short. The reason for this is indicated in Wyoming Station Bulletin No. 37 on the "Stooling of Grains." It is a general law that under adverse conditions plants strive to mature seed in order to reproduce themselves. Under these conditions then, grain will mature earlier and produce more seed in proportion to the rest of the plant than where everything is favorable to long continued growth.

TABLE I.—*Subsoiling for Wheat.*

Yields in Pounds per Acre.

		LARAMIE.		SHERIDAN.	WHEATLAND.	SUNDANCE.	
		Straw and Grain	Grain	Grain.	Grain.	Straw and Grain.	Grain.
First Year.	Subsoiled	2627	943	3000	1726	3920	1440
	Plowed	2863	997	2550	1614	3441	1160
	Gain			450	112	480	280
	Loss	236	54				
Second Year.	Subsoiled	2174	901	2700			
	Plowed	1894	876	1950			
	Gain	280	25	750			
Third Year.	Subsoiled	2170	908				
	Plowed	2127	833				
	Gain	43	85				

The increase in yield of wheat at Laramie the second and third years on the land which had been subsoiled is but little more than enough to balance the decrease the first season. At Sheridan there was an increase in yield the first year of seven and one-half bushels and the second year of twelve and one-half bushels on subsoiled land. At Wheatland and Sundance the increase on subsoiled land was small but was over twice as much at Sundance as at Wheatland.

The results with oats are given in Table II. The lengthening of the season for oats by subsoiling was more marked than with wheat. At Sundance the oats on the subsoiled portion of the plat seemed to be making better growth during the first part of the season but, when harvested, Superintendent Hoyt reported a smaller yield than was obtained from the land treated in the ordinary way. At Laramie the oats were later in reaching maturity on the subsoiled land. It may be stated that late varieties of nearly all crops, if not interfered with by frost, produce heavier yields than those which require only a short season in which to mature. Lengthening the growing season for the same variety would be expected to increase the yield, but at the high altitude of the land over a large part of Wyoming the time between late and early frosts is comparatively short and earliness in ripening is a most important factor. There was a slight increase in yield of oats the first two years, but the third season the decrease in crop was almost enough to balance the gains of the first two seasons, though whether or not the effect the third season was due to subsoiling may be questioned.

At Sheridan there was a loss of seventy pounds more of oats the first year than was gained the second year by subsoiling. At Wheatland there was a small increase on the subsoiled land, but the variation was small, probably not more than would be obtained on any two plats, though treated exactly alike. To all appearances the yields of oats were not materially influenced at any place by subsoiling the land.

TABLE II.—*Subsoiling for Oats.*

Yield in Pounds per Acre.

		LARAMIE.		SHERIDAN.	WHEATLAND.	SUNDANCE.	
		Straw.	Grain.	Grain.	Grain.	Straw.	Grain.
First Year	Subsoiled	4390	1520	3070	1898	1960	512
	Plowed	3898	1345	3360	1614	2224	648
	Gain	492	175	—	184	—	—
	Loss			290		356	136
Second Year.	Subsoiled	3555	1345	2700			
	Plowed	3378	1194	2480			
	Gain	177	151	220			
Third Year.	Subsoiled	3645	1302				
	Plowed	4445	1526				
	Gain	—	—				
	Loss	800	224				

Because of the high altitude with the accompanying short seasons and cold nights, corn is not grown at Laramie, so barley was planted on one portion of the subsoiled plat at this place and corn was grown at Sheridan, Wheatland and Sundance instead of barley. The results with barley and corn are given in Table III. It is doubtful if any effect on the yields of barley one way or another can be traced to the subsoiling. The first year there was less straw and more grain on the subsoiled land. The second year this was reversed, there being more straw and less grain where subsoiled, and the third year there was aproximately no difference in the production of straw, but there was quite a decrease in the yield of grain.

Subsoiling for corn did not pay at the sub-stations except at Sundance where a good increase in yield was obtained. At Sheridan there was quite a large decrease in yield of corn the first season, and no difference the second year. Superintendent Lewis reported that the corn did not mature as well on the subsoiled land. The first year the estimated yield on the subsoiled part of the plat was thirty bushels per acre, and on the land not subsoiled thirty-five bushels per acre. Ten per cent. of the corn on the land merely plowed ripened thoroughly, while all the grain from the subsoiled portion of the plat was soft and immature. The second season fifty bushels of mature and thirty bushels of soft grain per acre were harvested from each portion of the plat. To compare with others in the table, these yields have been reduced to pounds by using the weight of seventy pounds per bushel for corn in the ear.

At Wheatland during the season of 1896, the supply of water for irrigation was somewhat limited, and if the crops suffered for water, as they probably did to some extent, those on the subsoiled land would be expected to have the advantage. Mr. M. R. Johnson, the superintendent, states that all the crops made a better growth on the subsoiled land, that they seemed to withstand drouth better, and that the quality as well as the quantity of the product, indicated beneficial effects from subsoiling. The corn gave an increased yield of 363 pounds per acre on the subsoiled land.

TABLE III.—*Subsoiling for Barley and Corn.*

Yield in Pounds per Acre.

		LARAMIE.		SHERIDAN.	WHEATLAND.	SUNDANCE.
		Barley.		Corn.	Corn.	Corn.
		Straw.	Grain.	Grain.	Grain.	Grain.
First Year.	Subsoiled	2944	1325	2100	3590	3008
	Plowed	2989	1292	2450	2227	2416
	Gain	—	33	—	363	592
	Loss	45	—	350	—	—
Second Year.	Subsoiled	4602	1479	3500		
	Plowed	4123	1668	3500		
	Gain	479	—	—		
	Loss	—	189	—		
Third Year.	Subsoiled	2169	527			
	Plowed	2175	752			
	Gain	—	—			
	Loss	6	225			

Subsoiling for Root Crops.

The fact that deep soils are favorable for the growth of roots is recognized everywhere, and as would be expected subsoiling produced more marked effects on the yields of root crops than it did on grains. In Table IV., reporting the results with root crops, it will be seen that in every trial there was increased yield from the subsoiled land, and in some instances there are important gains. The lasting effect of subsoiling is well brought out in this table. All the tables show that, at Sherman, where the experiment was carried out two years, and at Laramie where results were obtained three seasons, the beneficial effect of subsoiling is greater the second year than it is the season the subsoiling is done. This indicates that it would be advisable to subsoil in the fall rather than in the spring. The third year the soil has probably become compacted again so the effect is much less than it is the first two seasons.

TABLE IV.—*Subsoiling for Root Crops.*

Yield in Pounds per Acre.

		LARAMIE.			SHERIDAN.		WHEAT-LAND.		SUNDANCE.	
		Potatoes	Beets.	Turnips.	Potatoes.	Beets	Potatoes.	Beets.	Potatoes.	Beets.
First Year.	Subsoiled			8605	12858	13860	2425	8302	8224	17161
	Plowed			8380	10620	12600	2151	8009	6960	14841
	Gain			315	2238	1260	274	293	1264	2320
Second Year.	Subsoiled	3672	12893			28700				
	Plowed.	2620	11643			24795				
	Gain	1052	1250			3905				
Third Year.	Subsoiled	6940	5450							
	Plowed.	6865	4522							
	Gain	75	928							

POTATOES—At Laramie the potatoes planted the first year failed to grow because the soil was too dry. The second and third years the stand was poor and small yields were obtained, but there was a good increase of crop on the subsoiled land. In Table IV. only the yields of potatoes which were of sufficient size for market are reported. The proportion of large and small tubers on the two kinds of ground and the increase in size on the subsoiled land is of interest. Table V. gives the yields of large and small potatoes, the percent marketable and the weight of the largest twelve tubers from each portion of the plat at Laramie in 1897 and 1898. The difference in yield in 1898 is small and there was practically no difference in the size of the potatoes, indicating that little effect on this crop was produced by the lower soil having been loosened up three years before. The second season after subsoiling, however, there was not only a large increase in the yield, but in the size of the tubers as well.

TABLE V.—*Effect of Subsoiling on Size of Potatoes.*

at Laramie, Wyo.

	1897.				1898.			
	Yield.		Percent. Marketable.	Weight of largest twelve.	Yield		Percent. marketable.	Weight of largest twelve.
	Large.	Small.			Large.	Small.		
Subsoiled	3672	1552	70.3	5.1	6940	2417	74.2	4.6
Plowed	2620	1660	61.2	4.5	6865	2212	75.5	4.6
Gain	1052	892	9.1	0.6	75	205		

At Wheatland the subsoiling produced little effect on potatoes. The increase in yield of marketable potatoes was only 274 pounds. Of the entire crop 62.8 percent were marketable on subsoiled land, and on the land not subsoiled the marketable tubers were 63.6 per cent of the whole crop. At Sheridan and Sundance the small potatoes were not reported, but at Sheridan the largest 12 tubers from subsoiled land weighed six and one-half pounds and from plowed land six pounds.

SUGAR BEETS—Subsoiling gave satisfactory increase in yields of sugar beets at every place except Sheridan. At

Laramie the increase in size of the beets is worthy of special mention. Not only were the largest twelve very different, from the two plats, but the average size of the roots was much larger on the deep soil. In 1897 the largest twelve roots from the subsoiled plat weighed nineteen pounds and from the plat not subsoiled twelve roots weighed eleven pounds. In 1898 the difference was less.

Twelve of the largest beets from the subsoiled plat weighed in the aggregate seven and one-half pounds and from the plowed land six and one-half pounds. Analysis of the beets showed slightly better results from the land not subsoiled. Beets from subsoiled land contained 19.7 percent sugar and had a purity of 88.2, while those from the adjoining plowed land contained 20.3 percent sugar and had a purity of 92.7.* The analyses were made from the crop of 1897, the second year after subsoiling.

SUBSOILING, IRRIGATION AND SOIL MOISTURE.

The subsoil plats were small, and as it was necessary to treat the crops alike on both parts of the plat, it was impossible to measure the amount of water used on each portion. An experiment was carried out with different amounts of water on the potatoes growing on the subsoiled land in 1897. Measurements were made of the total amount of water used on the plat, one-half of which was subsoiled and also on another subsoiled plat, and we are able to compare these measurements with the amount of water used on other fields. During the season of 1897 the Physicist made a series of moisture determinations on the different soils and published the results in Bulletin No. 35, a resume of which is shown in the accompanying diagram. These observations enable us to draw some conclusions in relation to the soil moisture and the use of irrigation water on such deeply tilled soils at Laramie.

In 1896 the barley, oats and wheat, were irrigated twice,

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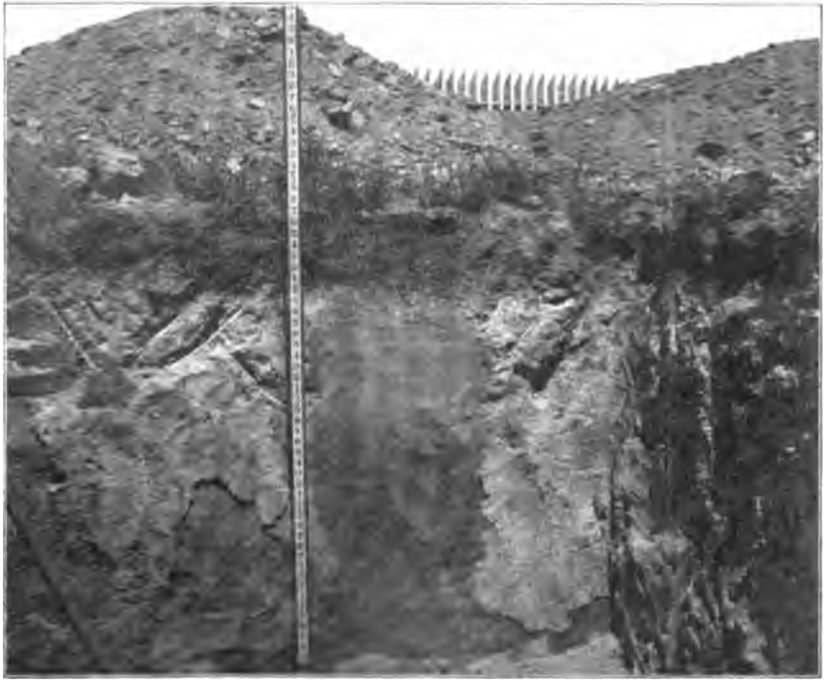
*See Wyoming Station Bulletin No. 36, Page 197.

on the acre of land one-half of which was subsoiled. At the first irrigation on July 2, enough water was applied to cover the land 11.4 inches deep and at the second irrigation enough water was applied to cover the land 6.12 inches deep, or a total depth for these crops of 17.52 inches. The precipitation for the year was 10.75 inches of which 4.75 inches fell during the months of May, June, July and August. This gave a total of 22.27 inches for the growing season or 28.22 inches of water for the year. The same year wheat and oats on other fields received enough water by irrigation to cover the land to a depth of 14.88 inches, and barley received 14.52 inches of water, showing that enough more water was applied to the acre, one-half of which was subsoiled, to cover the whole plat three inches deep. If this was due to the effect of subsoiling it means a requirement of six inches more water on the subsoiled land. Unfortunately the record of measurements of water on the subsoiled plat was broken, so it cannot be reported for 1897, but in 1898, trustworthy measurements were secured. The wheat, oats and barley were irrigated twice. On June 24, enough water was applied to cover the land 11.52 inches deep, and July 13 enough water to cover it 9.12 inches deep or a total of 20.64 inches. Including the rainfall, the land received enough water during the growing season to cover it to a depth of 25.22 inches, and in the year 28.26 inches. It is not possible to draw conclusions in regard to the effect of the subsoiling on this plat in 1898, as other crops of the same kind received varying quantities of water, some more and some less than this amount.

On another plat, however, which was subsoiled in the spring of 1898 and planted to oats, the amount of water used in irrigation was very large. The land was irrigated twice. At the first irrigation on June 27, enough water was used to cover the land 30.84 inches deep, and all of it was absorbed by the soil. At the second irrigation, July 11, enough was used to cover the land 13.44 inches deep,



FIVE FEET OF SOIL, LARAMIE FARM.
One Year after Subsoiling.

making a total for the season of 44.48 inches, or 3.69 feet. Including the rainfall, this gave a depth of water brought to this land in the year of 51.91 inches or for the growing season of 48.47 inches. The amounts of water used on other plats of grain in 1898, was 1.90 feet on one field of oats, 2.58 feet for oats on sod, 1.55 feet for oats and cultivated grain, 2.70 feet for one plat of barley, 1.74 feet for one plat of wheat and oats, and 3.63 feet for one field of wheat, which was irrigated three times and given an unusual amount of water.

The illustration of five feet of soil on the Experiment Station is made from a photograph taken one year after the subsoiling was done. The upper eight inches of dark soil is the portion turned over each year by the plow. The next six or eight inches of subsoil shows the effect of having been loosened by the subsoil plow, leaving it porus. On the native plains the soil below the first one or two feet may not have been wet for ages, as the natural rainfall is not sufficient to wet more than the first few inches of surface, and there is practically no difference in composition between the surface and subsoil. Breaking up the layer which is compacted by the plow in the bottom of the furrow gives the water a new reservoir below the plowed land and affords a means of escape by seepage, which would account for the large amounts necessary to soak it up when irrigated and perhaps also for easy dissemmination and loss of the moisture afterwards.

In 1898 the potatoes on the plat, one-half of which was subsoiled, were divided into two parts. One part was irrigated twice, using only a small amount of water each time and the other part was irrigated three times. Those irrigated twice received enough water to cover the land 2.04 inches deep on July 28, and 1.56 inches deep on August 4. The ones irrigated three times received the first irrigation on July 7, when enough was applied to cover the land 10.20 inches deep. At the other two irrigations they were given the same amounts as the potatoes which were irrigated but twice. The results are given in Table VI., which shows the amount of water applied and the yields on land subsoiled and not subsoiled.

TABLE VI.—*Potatoes with Two and Three Irrigations on Subsoiled Land.*

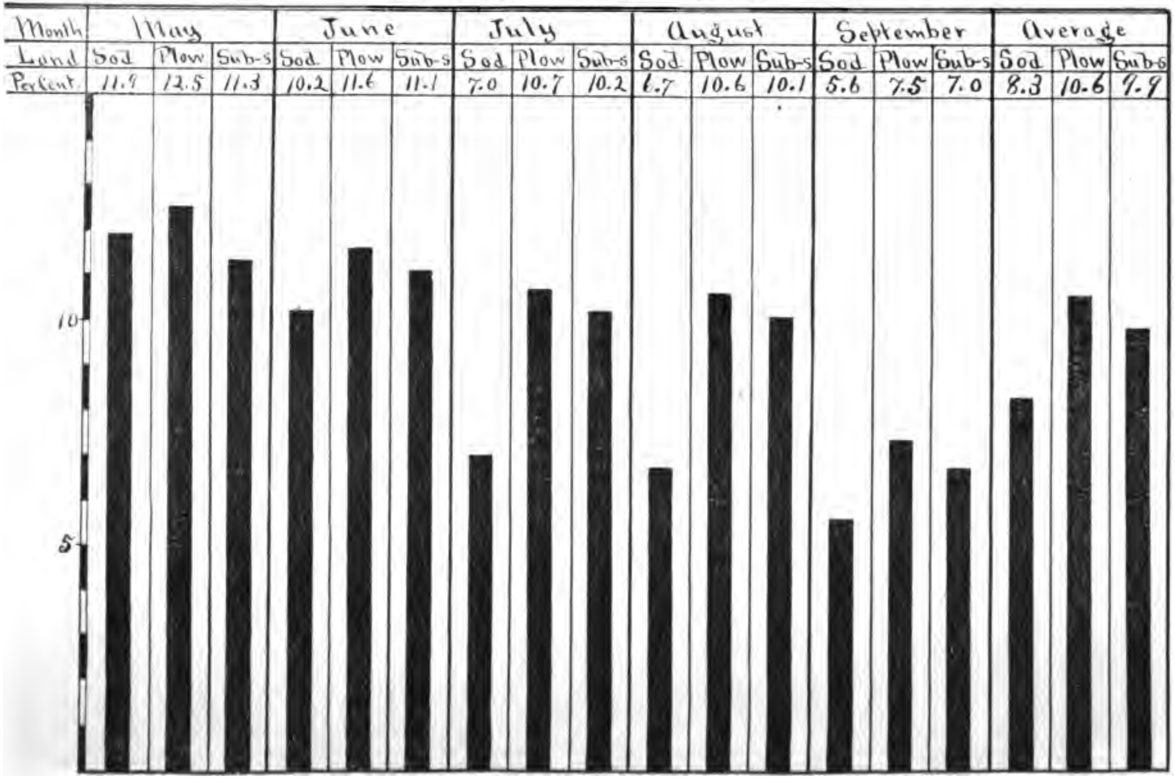
Laramie, Wyo., 1898.

	Total amount of water applied. Inches.	Yield on land plowed. Pounds.	Yield on subsoiled land. Pounds.	Average yield. Pounds.	Weight of largest twelve plowed. Pounds.	Weight of largest twelve Subsoiled. Pounds.
Irrigated twice	3.6	4972	5290	5131	3.6	3.9
Irrigated three times.	13.8	8759	8591	8675	5.6	5.3
Increase	10.2	3787	3301	3544	2.0	1.4

This shows an increase due to the increased amount of water applied, of over seventy-six percent on plowed land, and sixty-two percent on subsoiled land, the average increase being about sixty-nine per cent. The fact that increased water applied in irrigation did not increase the crop as much on subsoiled land as on the land which was plowed is in favor of the subsoiled land as it indicates that the crop actually needed less water to produce the same yield. This may be true, as the variation is small and may be accidental, and it is possible and probable that more water was actually absorbed by the subsoiled portion when irrigated. It is unfortunate that we are not able to make a like comparison the first and second seasons after subsoiling.

If moisture comes to the soil during any part of the year, the friends of subsoiling claim that it is retained and made more available to the crop. The study of the moisture in the soil of the different plats at Laramie in 1897, which was made by the Department of Physics, does not seem to bear out such statement. The accompanying chart illustrates the difference in moisture content of the soils on sod land, on land which was plowed in the usual way and on the subsoiled land. The determinations of moisture were made daily and these have been averaged for each month. The samples were taken to the depth of one foot by driving tubes about one inch in diameter into the soil. On the loose ground some of the soil might be driven down in front of the tube instead of entering it, but the samples were carefully taken and no effect of the kind was noted. The vertical black lines in the chart represent the average percent of moisture in the soil which is also expressed in figures at the top of each column. The last three columns at the right represent the average percent of moisture for the summer. The lowest moisture content observed was 2.52 percent in sod land, September 24. The highest percent observed was 22.25 on the land plowed but not subsoiled and immediately after irrigating it. The amount dropped to 19.7 percent the second day, and to 15.76 percent the third day. On the subsoiled part of the plat after irrigating the percent was 21.15 the first day, 21.76 the second day, decreasing to 16.23 the third day after applying the water. There is little difference in the average moisture of the surface soil on the plowed land and that subsoiled, but what difference there is shows less moisture on the subsoiled land throughout the summer. These facts indicate that more water was needed at Laramie to irrigate subsoiled land and less of it was retained by the surface soil for the use of the plants growing thereon. It is possible there was more water in the soil below the depth of these samples on the subsoiled plat, but the difference was not great enough to produce marked effects on the crops. At Sheridan the Superintendent states that more water was required at the first irrigation and less at the second on the subsoiled land. At Wheatland the crops seemed to be less affected by drouth where subsoiled. This may have been due to an excess of water absorbed by the subsoiled land when it was irrigated.

Soil Moisture, 1897.



DOES SUBSOILING PAY?

The test of the advisability of any operation on the farm lies in the final result measured in dollars and cents. Subsoiling is an expensive operation which more than doubles the ordinary cost of preparing the land for the crop by plowing. The cost of subsoiling will vary with the condition of the soil and the price of labor. The cheapest it could be done on large areas, and thoroughly done as in these experiments, would be at a cost of not less than three dollars per acre. Where we broke up the subsoil to a depth of fourteen to sixteen inches, on small plats the expense was five or six dollars per acre. Unless it increases the yield, improves the quality and therefore the value of the crop, or reduces the expense of producing it, or requires less water so the same supply will irrigate more land, the practice of subsoiling cannot be recommended as one to be adopted on the farm.

Referring to Table I. in which the yields of wheat on subsoiled land and on land prepared in the ordinary way are compared, it is evident that the accumulated increase for three seasons at Laramie would not pay the expense of one subsoiling. At Sheridan the increase of 450 pounds of wheat per acre the first year and 750 pounds the second due to subsoiling would give a total value of twelve dollars per acre more from the subsoiled land. If the subsoiling cost four dollars per acre more than the ordinary expense of plowing, the margin of profit is large enough. Even though we allow for a considerable increase in yields the second year at Wheatland and Sundance, subsoiling would not pay for wheat in these localities.

The results with oats as given in Table II. do not show any marked or uniform improvement in the crop. So far as our experiments may be relied upon as showing the true effects of subsoiling in this state, the indications are that it will not pay to so prepare the soil for oats. The same statement may be made for barley and corn unless it be at Sundance, where the increase the first year and the probability that there would also be a like increase in the crop the second year, indicate that subsoiling for corn might pay in that region.

Subsoiling for root crops did not give a return the first year at Wheatland, large enough to pay the cost, though the quality of the crop was improved and the increase the second season might leave a profit. At Laramie the increase in the potato crop the second year (see Table IV. page 11), would be worth $10.50 to $13.00 at the local market price. On the Sheridan farm the increased yield of potatoes the first year was worth from $11 to $20, and at Sundance from $6 to $12, depending on the market price. The value of sugar beets for stock food would make the increased yields from subsoiled land at Laramie, Sheridan and Sundance profitable. As a rule we believe that subsoiling for root crops will bring a profitable return.

Whether or not subsoiling will pay depends largely on local conditions and the kind of crop. Before adopting so expensive a system of tillage the farmer should satisfy himself in regard to whether it will bring a profit on his land by making small trials. Our results can not be said to indicate that subsoiling in regions which depend on irrigation will materially assist in saving the moisture or make irrigation less necessary. It is true that subsoiling apparently mitigated the effects of drought somewhat in Wheatland, though the increase in the value of the crop was not sufficient to pay for the expense incurred. It is possible that, where water for irrigation is scarce, and other conditions are favorable, subsoiling might make the water which is available go farther in maturing a crop, though we have been unable to prove any valuable saving of moisture where the subsoil is made porus.

SUMMARY.

The expense of subsoiling to depths of sixteen or eighteen inches is from three to six dollars per acre.

Subsoiling is probably more valuable in semi-arid or humid regions than where irrigation is practiced.

The effects of once subsoiling the land may continue for three or more years and under our conditions are more apparent the second season after the subsoiling is done than they are the first.

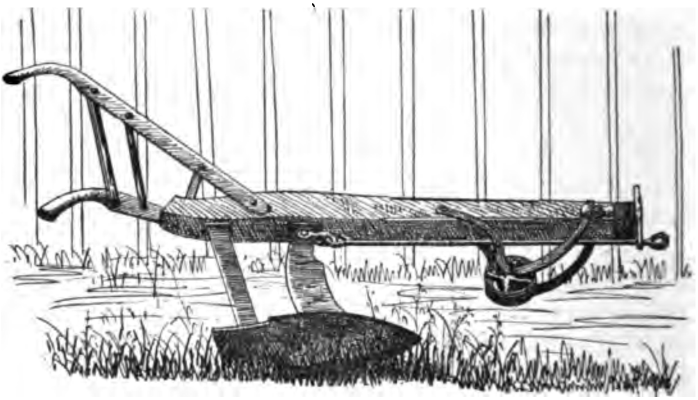
If subsoiling is to be practiced, we recommend doing it in the fall.

Subsoiling does not produce a uniform effect on the grains. Under certain conditions it may pay for wheat raised by irrigation. We have not found it profitable for oats, barley, or corn.

Grain takes longer to mature on subsoiled land. At high altitudes where the season is comparatively short it is doubtful if subsoiling for grain is advisable.

The quantity and quality of root crops are greatly improved by subsoiling the land. Subsoiling can be generally recommended in this state for potatoes.

Under our conditions subsoiling has increased the amount of water needed to irrigate the land and apparently is of little value in conserving moisture. However, if no water could be applied by irrigation during the summer, the filling with moisture in the winter or spring by rainfall or irrigation of the reservoir formed by subsoiling, would be beneficial.



UNIVERSITY OF WYOMING.

Agricultural College Department.

WYOMING EXPERIMENT STATION,

LARAMIE, WYOMING.

BULLETIN NO. 42.

DECEMBER, 1899.

Some Native Forage Plants for Alkali Soils.

BY AVEN NELSON.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyo.

Wyoming Agricultural Experiment Station.

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SOME NATIVE FORAGE PLANTS FOR ALKALI SOILS.

AVEN NELSON.

INTRODUCTION.

There are herds and flocks on a thousand hills. These are one of the great sources of Wyoming's wealth. Though events go to prove that we must more and more become an agricultural people, yet for years to come the most remunerative agriculture must be that which finds, in the stock interests of the state, its reason for being. Thousands of horses, tens of thousands of cattle and hundreds of thousands of sheep feed within our vast domain. Can the number now supported be increased? If not, then the stock industry has reached its maximum development.

If, as has been asserted, our ranges will no longer sustain the princely herds of the days of the "cattle kings," then we are no longer occupying one of the important vantage points of the state's material greatness. That the methods followed in the management of the stock industry have materially changed admits of no question. The present status has been evolved from the early conditions in which chance and speculation played so important a part. In the early days comparatively few men were able to launch out into so deep a sea or even cared to venture on such a perilous voyage.

Herds numbering thousands of head roamed over hills and plains with no supervision except the semi-annual "round-up" for branding or for "cutting out" those animals fit for market. Furthermore, even this supervision was largely that of the hireling, the owner's eye being too often absent and his will too often easily evaded.

With no provision for caring for the stock during unfavorable winters (those with heavy snowfall or following a season of drought), whole herds were decimated many times over and the fabulous profits, which had been so alluring, were swept away.

Such experiences have wrought and are still working their own reform. The speculative features are giving place to sounder business principles and the incomes, while less alluring, are far more certain.

The product of this evolution is smaller herds in the hands of many owners, more personal and interested supervision, provision for the care and feeding of stock during inclement weather and individual control of land either by purchase or lease. Are these conditions such as would tend to diminish the stock supporting capacity of the state? It would hardly seem so. The replacing of the bonanza business by everyday prosperity must multiply even the best of the former results.

It may seem at first sight, as if the enclosing of most of the irrigable lands is simply thus to withdraw from the available pasture lands those of greatest worth. Let it be remembered, however, that irrigation increases the productiveness of these lands many fold and the increasd product is, in most cases, a direct addition to the stock-supporting capacity of the lands. Not only are the products of these irrigated lands generally made to contribute directly to the support of the stock, but it is forage secured and preserved at a time when the open range furnishes an abundance, and fed out when this resource is no longer adequate. It will be seen that instead of decreasing the amount of stock in the state, the establishment of homes and farms ought to magnify the business in proportion to the increased yield of the lands, and that the profits ought to be enlarged by reason of the decreased losses. Whether we shall actually experience these results or not depends largely upon the way in which we use our resources. A proper appreciation of the native forage plants and a discriminating, commonsense use of the pasture lands of the state must govern us.

Probably it is true that the quality and kind of native forage is not identical with that of former years, since some species are less able than others to endure the heavy pasturing, the close cropping and the constant trampling to which they are subjected. In over-irrigation and in unwise methods in the application of water we find other causes for the extinction of some species. Indiscriminate flooding drives out many valuable grasses which are replaced by rushes and sedges, less valuable but for the fact that the yield is enormously increased above that of the unirrigated tracts.

If this extinction occurs in soils in which other hardier species do not readily replace them it is a loss that must ultimately seriously affect the total forage resources unless it is met by adequate counteracting influences.

How the range may be kept up to its old value is an important question, but how it may be improved is even more so. These are questions involving so many factors that their full discussion does not fall within the province of this bulletin, but a clearer idea of what is here aimed at may be had if we roughly classify and briefly characterize certain forage areas.

FORAGE AREAS.

The distinctive regions, which are utilized for pasture, in so far as native plants are concerned, are three. These each have their season and their peculiar advantages and disadvantages.

Mountain Areas.

This term is meant to include all tracts of country lying at an elevation of 8,500 feet or more. Mountain slopes, open or partly wooded, alpine parks, and even the seemingly naked summits become luxuriantly clothed for a few weeks with nutritious grasses. The always abundant moisture ensures a certain crop and the flowing stream is never far to seek for the thirsty cattle. July and August are the safe months in these situations which are of little value later in the year. Early snows soon make the stations untenable and the hard freezes of the lengthening nights convert the succulent grasses into dead mats of little value. Little can be done looking to the improvement of these areas. Here Nature must take her own course and we can only aid her by not taxing her resources too heavily. Overstocking this kind of range, where the climatic conditions are such that mature seed is produced but sparingly under the most favorable conditions, is simply to rob ourselves of our own heritage.

We are further confronted with our responsibility to these areas on account of their relation to the water supply of the plains below. Whether it be Forest Reserve or general public domain we are interested in maintaining the forest cover for the retention of the winter snows and the conservation of the resultant moisture. Heavy pasturing can not fail to ultimately seriously affect the renewal of the forest growth.

Hill Country.

Throughout the state at intervals occur ranges of hills, either only partly wooded or wholly denuded. Broad valleys, rounded summits and undulating foot-hills give perfect drainage to these fairly well-watered areas. They may be said to include all those portions of the state lying below an altitude of 8,500 feet, except the plains discussed below. Being well drained, these areas are reasonably free from alkali. In the broader valleys may occur considerable stretches which are capable of being irrigated. In these localities it is possible to materially increase the forage product either by furnishing more favorable conditions for the native plants or by introducing more productive species. However, these hill lands, as a whole, do not lend themselves readily to any schemes for their improvement. Cultivated and irrigated with difficulty our treatment of them must be protective rather than constructive. Overstocking should be avoided and periods of rest should alternate with periods of use.

This kind of range is, perhaps, in proportion to area, the most valuable that the state affords. Whether it is more desirable as summer or as winter range depends upon its particular location in the state and upon its exposure, factors which decide its relative climatic condition. Areas eminently satisfactory as summer range may be entirely unsuited for winter use on account of heavy snow-fall while other areas which, from lack of potable waters, are quite worthless as summer range may actually fatten great herds during the winter months. The most desirable winter range is not necessarily that of scanty snow-fall but rather one whose topography is such that the snow is, in the main, blown off of the slopes and open areas, forming drifts in the draws and under the brows of the hills. These drifts insure snow and water in abundance for the stock when water in the ponds and creeks is not to be had or is unfit for use.

The Plains.

We thus designate any large comparatively level area. The value of plains as grazing lands depends upon many factors, chief among which may be mentioned the amount of rainfall and the character of the soil. These are the determining factors of the character of the vegetation and makes necessary the recognition of two kinds of areas, viz., those which are free, or nearly so, from alkali and those which are heavily charged with it.

NORMAL PLAINS: By normal plains it is intended to designate those whose soil has no unusual or detrimental amount of alkali. The soil may be of varying degrees of fertility and the forage correspondingly scanty or abundant but no problems are connected with these soils and their crops except those that are common to the arid west in general.

Whether such regions are most valuable as summer or winter range is determined by the amount and character of the forage and of the water supply for the stock. In some portions of the state the plains become buried under the early winter snows while in other parts nearly similar plains are swept bare by the winds leaving an open range throughout the year. How to secure from such lands the best possible results must be left to be considered in some future bulletin *

ALKALI PLAINS: The soil in many portions of the state is heavily impregnated with alkali. These tracts occur in some of the more arid portions of the state as extended plains or as extensive, shallow basins; occasionally, as low, wet flats adjacent to streams and lakes, and now often as abandoned strips of a once fertile ranch. The latter are due to the accumulation of alkali carried to the lands by the irrigation waters or leached from the soils of the adjacent slopes. How to secure from such ranch lands profitable crops and from the larger alkali districts, forage of value are questions worthy of consideration.

RELATION OF PLANTS TO ALKALI.†

A question needing full investigation is the relation of plants to alkali or other salts in the soil. Practically all that we know is that some species have adapted themselves to endure or even to thrive in soil containing greater or less

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*The management of pasture lands and of the open range must vary in many respects. Little can be done for the improvement of lands which are not under individual control. Data are being accumulated regarding crop and pasture grasses and the treatment that each should have to give the most favorable results.

†This and the next two topics have been in part adapted from the writer's report upon the Red Desert of Wyoming.

amounts of various salts; that the seeds of most plants will not germinate in alkali soils because they are unable to absorb enough of the denser water of such soils. It has been shown that alkali retards germination or entirely prevents it in most seeds in direct proportion to the amount of the salt present[*]

Different species even in the same genus behave very differently in this respect; for example, Lambsquarters (*Chenopodium album*) seeks a soil free from salts, while for the Glaucousleaf Lambsquarters (*C. glaucum*) there can hardly be too much. If alkali affects a plant injuriously it seems to do so throughout its whole development.

Only a few families of plants contain species which have adapted themselves to a saline soil. Easily first as to the number of species in this respect is the Goosefoot Family (*Chenopodiaceae*). To this belongs a large number of distinctively alkali plants, such as the Salt-sages, White-sage, Greasewood, Russian-thistle, Australian Saltbush, etc. All of the native forage plants that are tolerant of alkali are contained in about a half dozen families. Besides the one already mentioned the next most important are the Grass family (only a few species) and a few species in the Sedge, the Rush, the Thistle (Compositae) and the Pea families.

VALUE OF ALKALI PLANTS AS FORAGE.[†]

The notion that often prevails that the small shrubs and weedy-looking plants of alkali lands have little forage value is an error. Inferior they may be to some of the choicest grasses but they are equal to many of the grasses and sedges that are cut for hay. As winter forage they are far superior to most of the grass-like plants after frosts have struck these down. As proof of this note the magnificent results that are attained in the Red Desert* the great winter pasture of Wyoming. If the winters are not too severely cold nor the snow too deep, all kinds of stock not only subsist upon these plants but actually remain in good flesh throughout the winter. These plants are much more succulent than appearances would indicate. Growing on strongly saline or alkaline soils, the Salt-sages and many other plants take up these salts in such quantity that one readily detects them on tasting even a small fragment of a leaf. Stock, feeding upon such plants, secures the necessary amount of salt from the food, so that the salting of stock that must be resorted to during the months when the animals are feeding upon the mountain grasses is wholly unnecessary.

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[*] Bulletin 29. Wyoming Expt. Station, by Prof B. C. Buffum.

[†] For an excellent summary of what is known of the relation of plants to alkali, and of the value of alkali-tolerant forage plants, see Forage Plants for Cultivation on Alkali Soils, by Jared G. Smith, in Yearbook of Department of Agriculture for 1898. The Experiment Station of the University of of California has also studied exhaustively many of the questions pertaining to alkali soils and the plants adapted to them.

INCREASING THE FORAGE SUPPLY.

In the earlier paragraphs of this bulletin, attention was called to the fact that the expansion or even the maintenance of the present stock industry is dependent upon the possibility of increasing the total amount of forage. No attempt will be made to show how this may be done except as to the forage of our alkali lands.† On the large areas of these not much may be hoped for by the expenditure of any ordinary effort or means but nature will here do much to bring about the desired result. According to the best information obtainable from many of our closest observers, the amount of forage produced each year is perceptibly increasing in some of the largest alkali areas of the state. In these localities the forage chiefly depended upon is shrubby in its character. The cutting down to the ground of such vegetation enormously increases the number of annual shoots.

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*For a full discussion of the alkali forage of the Red Desert of Wyoming see the writer's report to the U. S. Dept of Agriculture, published as bulletin 13 of the Div. of Agrostology.

†Probably in some future bulletin the character of the forage and the means for its improvement on lands free from alkali may be discussed.

From winter to winter this shrubby vegetation has been browsed down closer and closer to the woody bases of the plants, until now the tender annual shoots are produced in much greater abundance. The effectiveness of this browsing is, of course, dependent upon the region being used as a winter pasture only, giving time for growth and recovery each summer. If we so treat alkali plants of the greater plains that they shall have a chance to increase where they already occur, introduce them into the saline soils where they are not now found and, if possible, irrigate those that will respond to this attention by an increased yield, we shall see a marked difference in the stock-supporting capacity of the state.

Much can be done to make profitable the enclosed lands that originally were alkali lands or have become so through irrigation. Though they are generally considered worthless, yet highly satisfactory returns may be secured from them if they can be successfully seeded to alkali-tolerant plants. The kind of plants introduced will determine whether the crop may best be harvested or left on the ground as winter pasture.

The following brief list contains only such plants as are known to be more or less tolerant of alkali. Each is discussed with respect to this quality and as to its value as forage. Introduced plants that have proven of more or less value in some other places on alkali soils might be given but it is believed that the native forms are quite as likely to give favorable results, under the conditions existing here, as any of of the introduced ones.

THE SALT-SAGES.

Among the plants suitable for alkali soils, easily first are the Salt-sages or, as they are sometimes called, the Salt-bushes (Species of *Atriplex*). Many of these are exceedingly nutritious and constitute a large percentage of the forage in some of the arid, alkali plains. Some of them are reproduced each year from seed but many of them are perennials with merely a woody base or sometimes the whole plant quite shrub-like. The perennials are more valuable as pasture plants than the annuals, though they are more difficult of introduction, but, when once established, should yield without further attention forage of much value. Of the perennial species the following are of most importance for this state, as judged by their present relative abundance and adaptability to our alkali lands.

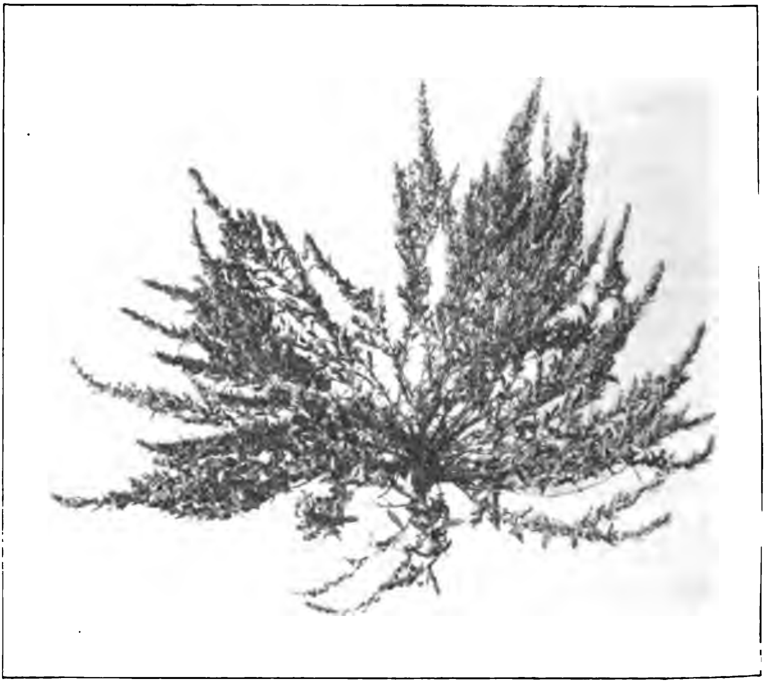

PLATE I.* Nuttall's Salt-sage (*Atriplex Nuttallii* Wats.).

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*I wish to acknowledge the valuable assistance rendered by Mr. A. H. Danielson in the preparation of the photographs from which these illustrations were made.

Perennials.

NUTTALL'S SALT-SAGE,—Plate I and Fig. 1, Plate III. (*Atriplex Nuttallii.*) This is by far the most widely distributed of the Salt-sages, being common throughout the interior arid west. It is less tolerant of alkali than the following species, occurring principally in soils where salts occur in moderate amounts only. It is essentially a plant of the greater plains where it sometimes occurs in the greatest abundance. Especially for sheep it has no superior as winter forage. From its woody base. it each year puts out a large number of stems which spread loosely in all directions. These are seldom more than a foot long, are quite leafy below and produce a great abundance of very nutritious seed. Its deep set roots and woody base enable it to endure much hard usage but these characters in connection with its slow growth make it unsuited for any use except permanent pasture. It is difficult of introduction but where well established care should be taken not to destroy it. Seed, however, is readily obtainable.

OSTERHOUT'S SALT-SAGE,*—Fig. 2, Plate III (*Atriplex eremicola*). This species resembles the preceding in many respects but it has a heavier, harsher woody base, is more erect in habit, grows to about the same size and has probably about the same forage value. The advantage that it enjoys over the preceding is that it is more tolerant of alkali, apparently thriving best on the borders of lakes and ponds where the surface is quite encrusted with the salt. In soils where the preceding will not grow this might be substituted were not the following a far more promising species.

NELSON'S SALT-SAGE,—Plate II and Fig. 3, Plate III, (*Atriplex pabularis*). Of the native perennials this is the one most worthy of trial as a crop plant. So far it is only known from south-central Wyoming where it occurs in greater or less abundance in the vicinity of alkali lakes and on the banks of similar creeks, e. g., Bitter Creek, in the Red Desert. Unlike the two preceding, its woody base is almost wholly underground, the numerous annual stems are nearly erect, very leafy and decidedly herbaceous in

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*In habit this so much resembles the preceding that no illustration of it as a whole has been introduced.

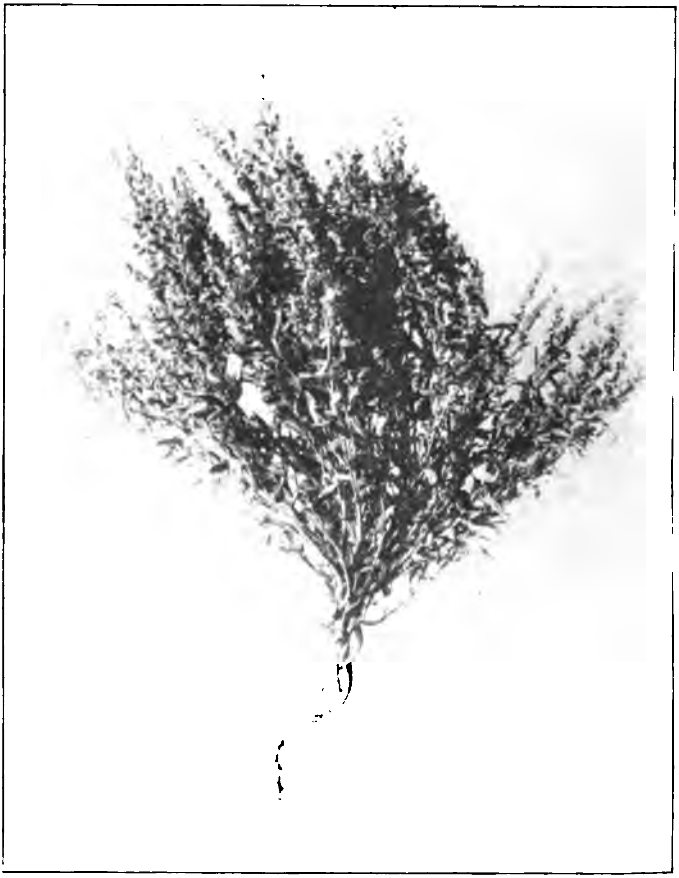

PLATE II. Nelson's Salt-sage (*Atriplex pabularis* Aven Nelson).

character. It also differs from the others in the close, continuous growth that it makes but resembles Osterhout's Salt-sage in that it is at home on the strongest alkali soils. Though best suited for a pasture plant, yet its erect habit and the herbaceous nature of the stems make it possible to harvest a crop of this with the ordinary machinery.

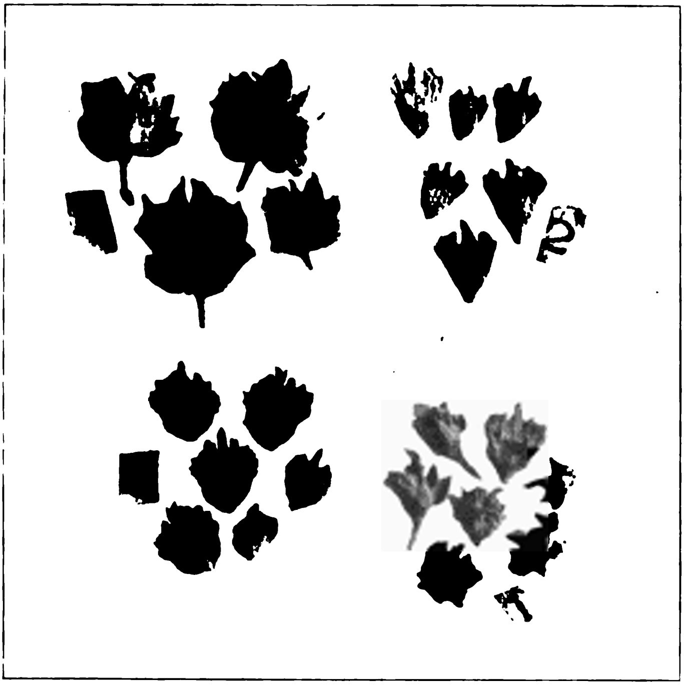

PLATE III. Seeds (technically fruits) of some perennial Salt sages: 1. Nuttal's Salt-sage. 2. Osterout's Salt sage. 3. Nelson's Salt-sage. 4. Bushy Salt-sage.

BUSHY SALT-SAGE,—Fig. 4, Plate III (*Atriplex canescens*). This species of Salt-sage is decidedly woody, sometimes a shrub several feet high. Its leaves and abundant seeds are greatly relished by all browsing animals, so much so that it is being largely exterminated where it is accessible to stock at all times of the year. It is not abundant in Wyoming, belonging rather to a range to the south and west of this state. On account of its shrubby character it can hardly be recommended for introduction.

Annuals.

Some of the annual species are very tolerant of alkali, grow rapidly, often forming plants of great size, and produce seed in the utmost profusion. It is doubtful if the forage value of these is equal to the perennial species and as winter pasture they have little value. On strongly saline soil where nothing else will grow and from which prompt returns are desired these may be properly tried. To secure the best results the crop must be harvested just before maturity in order that the seed may be retained. Of the several species in the state the three briefly describel below are the most promising.

PLATE IV. Spreading Salt-sage (*Atriplex expansa* Wats.).

UTAH SALT-SAGE,—Fig. 1, Plate V (*Atriplex truncata*). This branches rather freely from the base, its branches spreading loosely in all directions and producing a wealth of succulent leaves. It is less tolerant of alkali than the two following but is very generally distributed on the arid, alkaline plains. It is probably more readily introduced than the plants that are native on the more strongly impregnated soils.

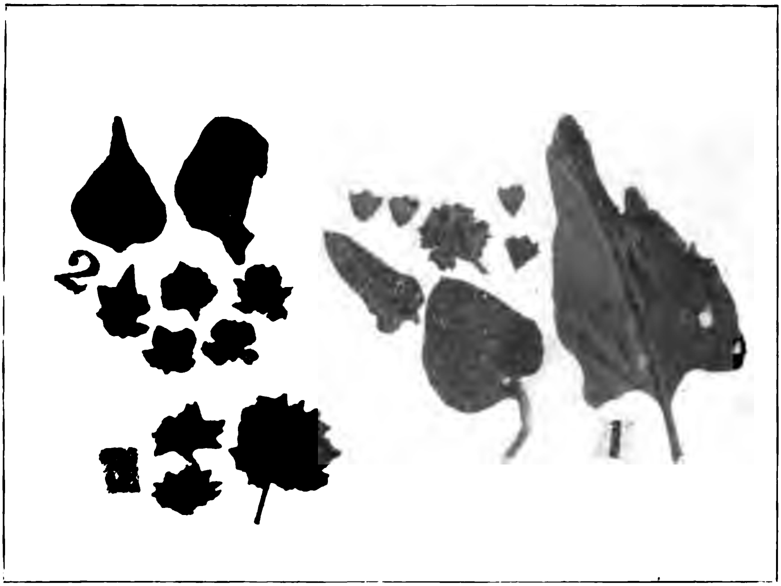

PLATE V. Seeds (technically called fruits) and leaves of some annual Salt-sages: 1. Utah Salt-sage. 2. Spreading Salt-sage. 3. Tumbling Salt-sage.

SPREADING SALT-SAGE,—Plate IV and Fig. 2, Plate V (*Atriplex expansa*). Very similar to the last but more freely branched and with much smaller, somewhat triangular leaves. This occurs on soils often quite encrusted with alkali, makes a dense and vigorous growth and yields a large quantity of fair forage which, like the preceding, must be harvested before it becomes dry and brittle.

TUMBLING SALT-SAGE,—Plate VI and Fig. 3, Plate V. (*Atriplex volutans*). In this plant we have a typical tumbleweed. It branches so freely and intricately that by autumn it is a dense, subspherical mass. At maturity the slender tap-root becomes brittle and soon breaks, after which the plant is rolled hither and yon by the winds, scattering its seeds at every bound. It does not seem to be widely distributed, being scarcely known except in the alkali basins and on the shores of alkali lakes. On lands that have been abandoned because of progressive accumulation of alkali this may prove to be just the desired plant. If sown thickly it would shade the ground, preventing further rise of the salt, absorbing much of it in its growth and producing at

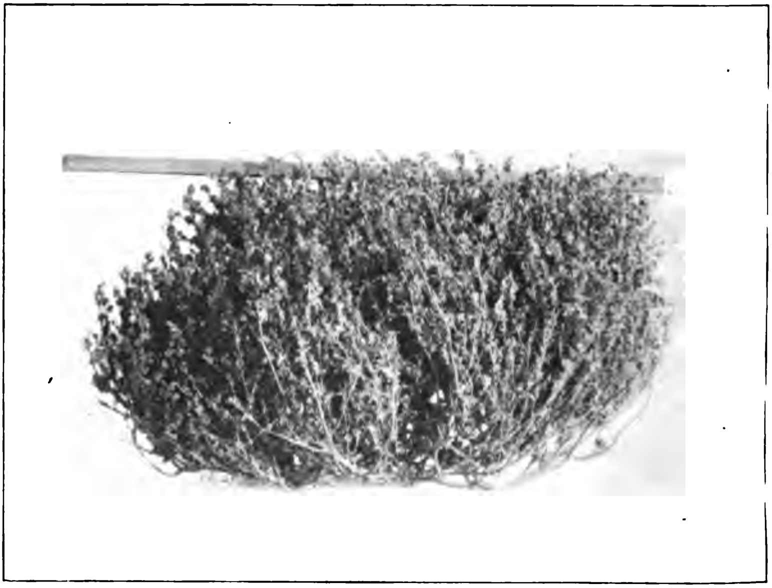

PLATE VI. Tumbling Salt-sage (*Atriplex volutans* Aven Nelson).
The meter stick lying on top serves to indicate the size of the plant.

the same time a great amount of coarse forage. If harvested a little before maturity and preserved in a silo it would probably yield a superior product.

WINTER-FAT.

WINTER FAT,—Plate VII and Fig. 1, Plate VIII. (*Eurotia lanata*). In this near relative of the Salt-sages (sometimes called Sweet-sage) we have another plant that is tolerant of alkali and of much value as a pasture plant. Though it is widely distributed in the state yet it is not now very plentiful since stock seek it so eagerly that it is becoming exterminated in many places. The numerous herbaceous branches which spring from the woody base are rather densely white hairy and become during the season about a foot long. These are often literally loaded down with the characteristic, white cottony seeds. It thrives on cultivated ground, makes a rapid growth and provides winter pasture of great value, especially so since (so it is said) stock feeding upon this plant are remarkably free from disease on account of its tonic properties.* Since it is not difficult to find small patches in enclosed grounds from which seed may be obtained ranchmen will no doubt find it worth their while to give this valuable plant a trial.

THREE GRASSES.

Among the native species of grasses there are very few that can be recommended for cultivation on alkali soils: There are several species that will exist in such soils but only a few that will prove profitable as pasture or crop plants.

INDIAN MILLET,—Plate IX and Fig. 2, Plate VIII (*Eriocoma cuspidata*). This is not strictly an alkali grass. In fact it will not endure soils containing a very large percentage of salt. It is included here because it is one of the import-

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*Yearbook of the Dept. of Agriculture, p. 547, 1898.

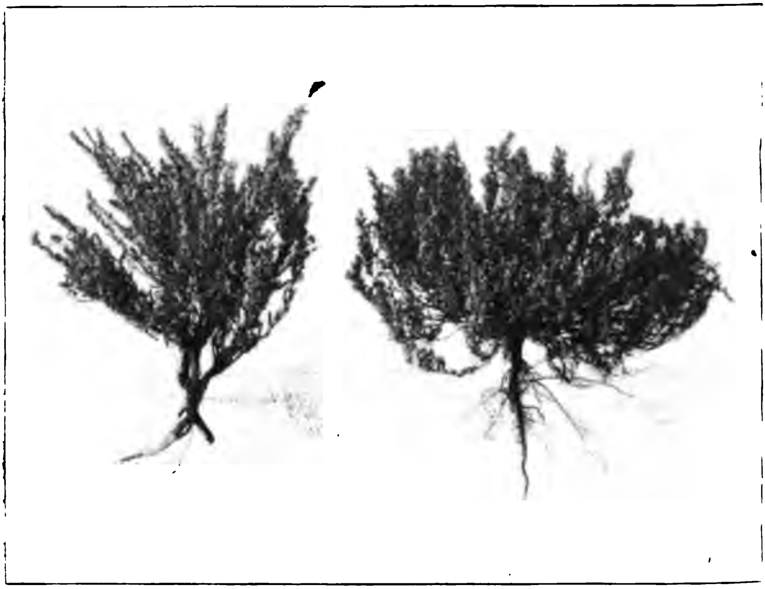

PLATE VII. Winter-fat (*Erotia lanata* (Pursh) Moq.).

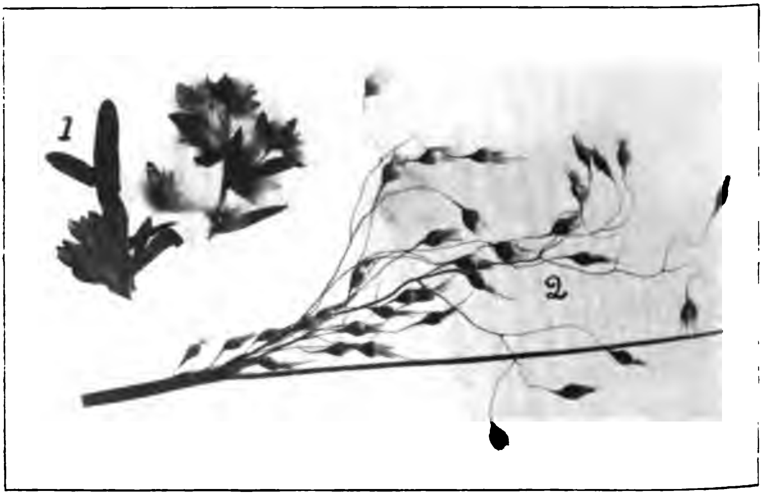

PLATE VIII. 1. The tips of two branches of Winter-fat. 2. Head of Indian Millet.

ant pasture grasses on the dryer alkaline areas of the interior west. It is one of the bunch-grasses, forming dense tufts from a few inches to a foot or more across. In no region is it so dry and sterile that it will not live but in better soil and with more moisture it becomes even prolific. Often but a few inches high yet under favorable conditions it attains the height of a foot or two. In any case it fruits abundantly and may be easily known by its large, peculiarly branched spreading panicle and large silky seeds. All

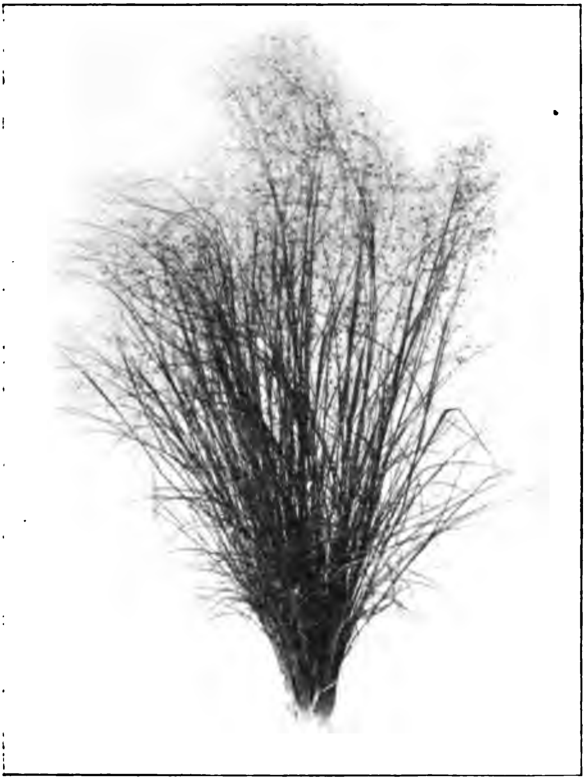

PLATE IX. Indian Millet (*Ericoma cuspidata* Nutt.).

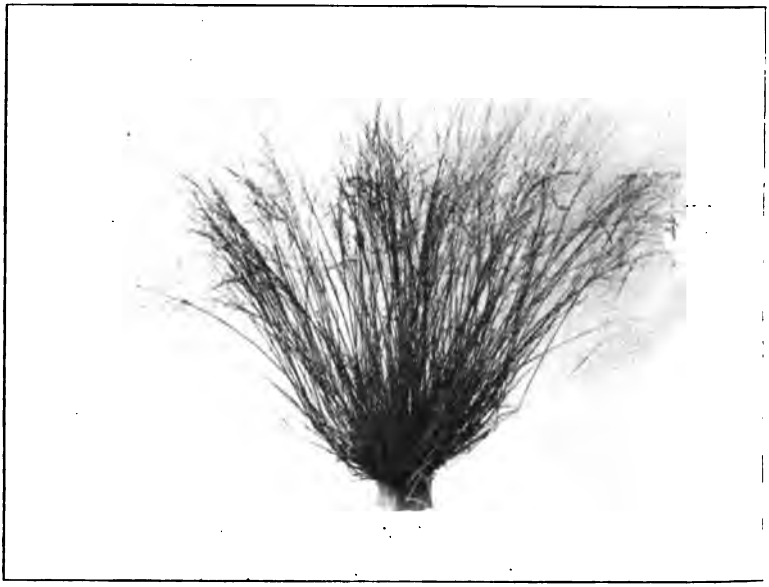

PLATE X. Alkali Meadow-grass (*Puccinellia airoides* Coult. & Wats.).

kinds of stock relish this plant but horses are especially fond of it and seem do well upon it. It is easily grown from seed as it germinates readily and reaches its best development in loose or sandy soil. It is often adventive in cultivated ground and on the loose slopes of railroad embankments.

SLENDER WHEAT-GRASS,*—Fig. 1, Plate XI. (*Agropyron tenerum*). Among the native grasses of the west there are none that will surpass in value the Wheat-grasses. Many species of these not only grow luxuriantly but represent forage of very high nutritive value. Several species are tolerant of alkali but, as it happens, the one that is best adapted to soils of this character is also in many other respects the most desirable as a meadow grass. Slender Wheat-Grass makes a meager growth in dry sterile soil, but it responds promptly to all cultural advantages. The writer has seen wonderful results from seeding the ground to this grass, and this, too, where the soil was strong with alkali and the water used for irrigation was far from the best. It forms a close uniform growth that yields as much per acre as an average field of Timothy. Since it thrives best with a very moderate amount of water (it will not endure flooding) no more profitable grass can be found for saline areas of limited water supply. While not seeding very freely, the requisite amount for sowing can easily be obtained after the first crop has been harvested. It is easily thrashed out in a machine or may be flailed out if no better method is at hand. Seed of this grass is now on the market.

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*The Wheat-Grasses are so well known that no illustration is considered necessary except one of the head of this species. By this, it may be distinguished from the other species.

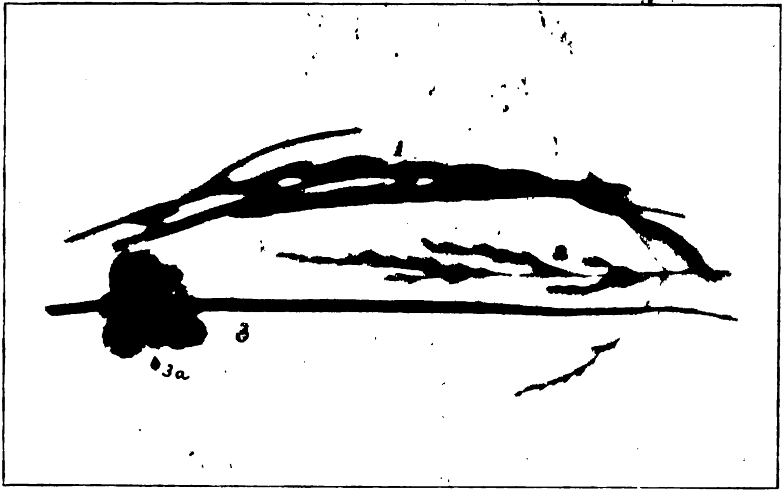

PLATE XI. 1. Heads of Slender Wheat grass. 2. Head of Alkali Meadow-grass. 3. Head of Tuber Bulrush. 3a. A single seed of Tuber Bulrush.

ALKALI MEADOW-GRASS,—Plate X and Fig. 2, Plate XI (*Puccinellia airoides*). Here we have a grass that is at home on the salt encrusted margins of ponds and lakes and on wet efflorescent flats where other grasses are wholly wanting. In such situations it grows luxuriantly, making a crop of much value but for the difficulty of harvesting it. Though of less nutritive value than some other grasses yet if cut in its prime it would make tolerable hay. Browsing animals greedily devour it but often it grows in boggy, inaccessible places. On abandoned alkali flats which can be flooded early in the season but which can be entered later with horses and mower this should be a profitable crop.

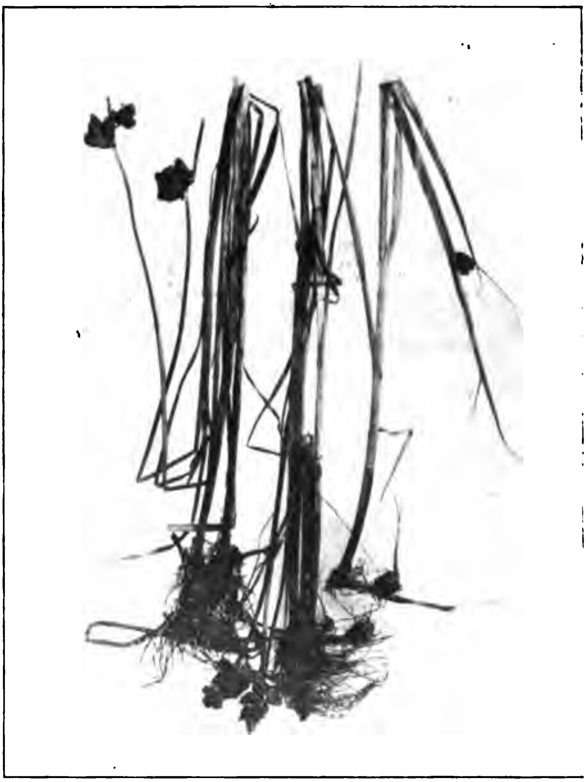

PLATE XII. Tuber Bulrush (*Scirpus paludosus* Aven Nelson).

It produces a fair amount of seed but unless harvested promptly, as it nears maturity, much of this is lost. Even as a pasture grass it has little value after it has reached maturity.

BULRUSHES.

Though there are several Rushes and Bulrushes that occur in alkali soils and have some slight forage value, yet there is but one known to the writer that is sought out by stock when other feed is abundant. This is the

TUBER BULRUSH,—Plate XII, and Fig. 3, Plate XI. (*Scirpus paludosus*). It never reaches maturity if it is accessible to cattle. They will wade about for it in places where they are in imminent danger of becoming mired. Like the grass last described above it will thrive best where the alkali is the densest. Even on recently dry lake beds, covered inches deep with the white salt, this species still develops apparently uninjured. Its best development is attained in alkali marshes that become dry late in the season. In such situations, if stock be kept out, it makes a dense, uniform growth and attains a height of 18 to 24 inches. Leaves are produced in abundance and the head-like cluster of spikelets are so richly supplied with large plump seeds that it is an easy matter to collect quarts of them by hand in a few hours. Though the seeds are retained by this plant most remarkably well yet none are more easily thrashed out and cleaned than this.

To secure perpetual returns from lands so thoroughly filled with alkali as to be worthless as regards other crops seems more than possible if seeded to this. Being an herbaceous perennial of the most persistent character it should maintain itself indefinitely where it is once introduced. Each year's new stems spring from the tubers produced the previous year at the end of short underground stems, and by this character and mode of development this species may easily be recognized.

UNIVERSITY OF WYOMING.
Agricultural College Department.

WYOMING EXPERIMENT STATION,
LARAMIE, WYOMING.

BULLETIN NO. 43.

MARCH, 1900.

ALFALFA AS A HAY CROP.

ITS CULTURE AT HIGH ALTITUDES.
TURKESTAN ALFALFA.
ALFALFA AND ALKALI SOIL.
IRRIGATION OF ALFALFA.

BY B. C. BUFFUM.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyo.

Wyoming Agricultural Experiment Station.

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ALFALFA.

(Medicago sativa.)

B. C. BUFFUM.

Much has been written about alfalfa in other states. Station literature, reports of Boards of Agriculture and the agricultural periodicals contain many accounts of experiments in growing, and investigations of the value of this forage. No other plant which has been widely grown in the arid region is held in such high esteem by those who have had the largest amount of experience in irrigation farming. The ease with which it is grown, its hardiness under trying conditions, the large yields produced year after year from a single planting, its distinctive value as a fodder and its power of improving the soil upon which it grows to such an extent that no expensive means of keeping up fertility is necessary, has brought alfalfa near to the hearts and pocket books of intelligent farmers and makes it a boon whose value can not be estimated.

In this bulletin it is not our purpose to give an account of experience with alfalfa in other regions, but to report briefly the results of our own investigations; indicate methods of culture which will insure success and give information of the return that may be expected under our own peculiar conditions of soil and climate. The question of raising alfalfa at altitudes under six thousand feet in the state, where it can be irrigated, is a comparatively simple one. It will grow on poor soil if in good tilth, not too strongly alkaline and with good drainage, and when once established it only requires irrigating and harvesting from two to four times each season. As the altitude increases and conditions become less favorable more care is required to secure a stand and over seven thousand feet above the sea, in dry and naturally exposed positions, specific treatment must be given to insure success. By the term "specific treatment" we would not convey the impression that great expense must be incurred to secure a productive meadow or that any practice which is beyond the ability and means of every ranchman is necessary. We have demonstrated that alfalfa can be raised on the Laramie Plains at small cost and that the resulting crops of hay will be remunerative to the man who exercises as much care and judgment as he would to raise a crop of oats.

Several ranchmen who first attempted to grow alfalfa on the Laramie Plains failed because they used wrong methods of preparing the soil and sowing the seed or because the crop was left to care for itself after sowing. From these failures the belief became widespread that making a success of raising alfalfa at this altitude, under our conditions of exposure, drying winds and short seasons, was out of the question. When the Experiment Station was established at Laramie I was warned by one of our large ranchmen that any attempt we might make to grow alfalfa would surely result in failure, and that it would be unwise for us to spend any of the station funds in experiments with it. This ranchman stated that he had spend five hundred dollars in his efforts to grow alfalfa on his ranch and was fully convinced that we would never be able to produce alfalfa hay in this region. When questioned in regard to the method he had pursued he said the ground had been carefully prepared by plowing, the alfalfa seed had been sown broadcast and harrowed in, but none of it grew.

Our first attempt to grow alfalfa on the station farm in 1891 failed.* The seed was planted on sod the first year it was plowed. With the seed was a goodly supply of dodder, a parasite which destroyed the young alfalfa plants. Some alfalfa seed sown on sod without plowing also failed, but since that time many plats and fields have been planted to alfalfa and we have not had occasion to record another failure. After we had been growing alfalfa for a number of years and had good fields of it close to the county road to demonstrate to passers by that it was successful, many ranchmen were still suspicious, and unfortunately, at the present time, some seem to entertain the idea that we have followed some secret or expensive system of culture to make it grow. They believe that our flourishing fields are deceptive and that it is beyond their power to secure like results. Only a year ago one ranchman who had become convinced from what he saw and what we told him of our experience, that alfalfa was a practical crop to grow, applied to a merchant in Laramie for some seed to be sown on his ranch. The merchant assured him that he could not afford to 'coddle his alfalfa, as he said, "go out and cover it up nights, the way they do on the Experiment Farm," persuaded him to give up the attempt to grow it himself and, I believe, sold him seed of alsike or something else which had not been demonstrated a success here. He has lost a year's growth of alfalfa and we are informed, regrets that he planted alsike.

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*See Bulletin No. 16, Wyoming Experiment Station, "Grasses and Forage Plants," page 232.

To trace the reason for such a prejudice is difficult and it is only necessary to say that such ideas are based on complete misconception of the purposes for which the station is established and supported. The experiment stations are established and operated for a single purpose and that is to benefit the farmers by investigating the problems in which they are interested and can not afford to investigate for themselves. But one thing is asked in return and that is that the results of these investigations be accepted and made use of by the farmer for his own personal pecuniary advantage.

The range stockman of a dozen years ago could make use of thirty or more acres of public domain for the support of each steer. He drifted away from the habit of tilling the soil and became constitutionally opposed to that occupation. The palmy days of the open range are gone and the inevitable may as well be accepted, that as land becomes scarce that which can be irrigated will be cultivated. It has become necessary to support each head of stock on a small fraction of the land which was formerly available. Irrigating native meadows has greatly increased the production of wild hay. Substituting such cultivated forage crops as alfalfa will double or treble the production of hay and the prosperity of the ranchman and farmer who makes proper use of his products will correspondingly increase.

ALFALFA CULTURE.

The culture of alfalfa is simple, but failure often results from wrong treatment. Under favorable conditions no crop is more easily grown, but there are correct methods of procedure in alfalfa culture which it is important to know and make use of everywhere. Under our high altitude conditions, the farmer who would be sure of his success must sow his alfalfa seed on the right kind of land and in the right way; have the soil properly prepared and give the crop that attention afterward, which will prevent its dying from drouth, or from excess of water, or succumb to any of the ills due to pure neglect. The farmer should remember that alfalfa has been a cultivated plant longer than the history of the Christian era, having been cared for by man for over

2,000 years and introduced into parts of the world widely differing from its native home.*

Although it is a perennial plant it has little more tendency to go wild after planting, and care for itself under our conditions, than wheat, which everyone understands would be lost to the world if not cultivated by man. However, alfalfa is one of the hardiest forage plants known. It will adapt itself to widely differing conditions. When a stand has once been secured, it resists drouth remarkably well, will stand as much or even more heat and cold than other cultivated plants or our native grasses and will last longer under continous cropping than will the best native meadow, producing each year from two to four times as much hay. As alfalfa is one of the easiest crops grown at low altitudes, farmers as a rule do not practice the careful methods here outlined, but it is just as inexpensive to follow a right method as a wrong one and ultimately is much more profitable. At high altitudes where the growing season is short, the nights cold and the winters long and dry, specific treatment becomes necessary to insure success. The hints for its culture here given are especially for high altitudes, though they are generally applicable to all portions of the state.

KIND OF SOIL—Alfalfa thrives on any good soil and in some places on comparatively poor soil, though it prefers a warm, sandy loam. Instead of recommending soils and locations for alfalfa we will briefly point out three or four things to avoid. Do not plant alfalfa seed in soil so strongly impregnated with alkali that there is a white incrustation of salt on the surface during part of the year. (See discussion of alfalfa and alkali soils on another page). Do not sow seed on low land where the drainage is not good. Alfalfa will not live where free surface water stands as near the top of the ground as one or two feet and any attempt to grow it on low, wet soils will result in failure. Water standing around the plants for any length of time from to much irrigation will surely destroy them.

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*Alfalfa is a Spanish name said to be derived from an Arabic word meaning the best fodder. In Europe it is known as lucerne, but originally this species was probably a native of some part of Asia. Its scientific name, Medicago, comes from the Greek, Media, a country which extended east to the Caspian sea. It was introduced into Rome from Media about 470 B. C. From there it spread into Spain and the Spaniards brought it to Mexico about 1520. Nearly fiftv years ago it reached the United States by being introduced into California from Chili, South America.

Alfalfa is a deep feeder. Usually it will not do well on a shallow soil underlaid with hard pan which prevents the strong tap roots from going deep into the subsoil. We have grown several good crops of alfalfa on land which had only from twelve to eighteen inches of surface soil, being underlaid with hard pan composed of gypsum and lime. This land has good slope and drainage. While good crops have been secured it has been necessary to exercise great care in irrigating and a large amount of water, or rather numerous irrigations, have been required to keep the plants from suffering, as the roots could not reach deep into the soil for moisture. A shallow soil over sand or gravel which both provides good drainage and allows the roots to sink deep into it, would be better than the same soil underlaid with hardpan. Many ranchmen have inquired whether or not we would recommend planting alfalfa on bottom lands along the river. As a rule we believe upland is to be preferred, as the soil is usually deeper and better drained. If the bottom land is comparatively free from alkali, and the surface is not too near the water level at any season of the year, alfalfa will succeed, and when it has become well established will probably require less irrigation than on upland, as the roots will go down far enough to reach the moisture supply below.

PREPARATION OF THE LAND.—Much depends on the condition of the soil upon which seed is sown. Alfalfa

Alfalfa. Loading on wagon, Laramie, 1899 Wyoming Experiment Station.

Stacking Alfalfa. Wyoming Experiment Station, at Laramie

seeds are small and the soil should be correspondingly well prepared, fine and moist. We do not recommend planting alfalfa on sod land under any conditions. At low altitudes in this State a good stand may be secured the first year after breaking up the sod but I have never known of such an instance at altitudes over six thousand feet and it will probably never pay to sow the seed on stiff or heavy sod which has not been plowed. An alfalfa meadow is practically permanent and will well repay the expense of preparing the soil and sowing the seed in the right way. If a piece of sod land is to be converted into an alfalfa field it should be plowed and planted to oats or some other crop the first year or two in order to put the soil into the right physical condition for the alfalfa seed. We think it best to have the soil somewhat compact for the seed and find it better not to sow alfalfa on newly plowed ground. A good stand of plants will be secured with more certainty on land which has been fall plowed or on stubble which is merely disk-harrowed and planked and again lightly harrowed to form a thin top mulch of loose soil which will prevent the rapid loss of water by evaporation. In case it is desired to sow alfalfa on land which is plowed the same spring, plowing should be done as long before sowing as possible, and the newly plowed soil may be rolled or heavily planked to compact it and afterward lightly harrowed to leave the surface finely pulverized. On loose, newly plowed land there is danger of drilling the seed too deep and the crop will fail because the small seeds are unable to push out of the ground.

Young alfalfa plants are quite tender and must be given no rough treatment until they have become well established. Should the soil be too dry to germinate the seed it may be irrigated to bring the plants up if carefully done and the land does not slope so much that the soil will wash away. If there is danger of the soil becoming too dry to germinate the seed and support the plants during the first two or three weeks of growth, irrigating should be done before plowing the land and the moisture saved as long as possible by harrowing after plowing or rolling the soil. We have never failed to get the seed to come up without irrigation where sown with the press drill.

While alfalfa has the power to take nitrogen from the air and will grow on very poor land, at least that which is poor in humus, as is often the case with our arid soils, we know of two instances on the Laramie Plains where the young plants were much stronger and made better growth the first year on land that was given a light dressing of stable manure. Mr. Webber sowed some alfalfa on land that had been manured and thinks the results more than paid the extra expense. On the Experiment Farm alfalfa made much stronger growth when planted on land that was fertilized with twelve loads stable manure per acre. The application of manure is not necessary, but where for any reason the struggle to become established is unusually great and such application can be cheaply made, the effect in producing strong young plants may well repay the extra trouble and expense. A strong point in favor of alfalfa is its power to grow on, and improve soils which have been worn out by other cropping.

WHEN AND HOW TO SOW THE SEED.—The young plants need to become as well established as possible, and have time to throw their roots deep into the subsoil for moisture, before going through the long winter. To enable them to do so the seed should be sown in the spring and as early as danger of hard frosts, which would destroy the young plants, is past. Another advantage of sowing early is that our spring months are our months of greatest moisture. Usually enough moisture comes to the land by rain to secure germination and provide for the early growth. On the Laramie Plains the seed may be sown any time in May. As the seeds germinate quickly it is probably safer to sow after the tenth of May than before that date. At altitudes in the state below six thousand feet, April is to be preferred, though the seed may be sown at any time up to July.

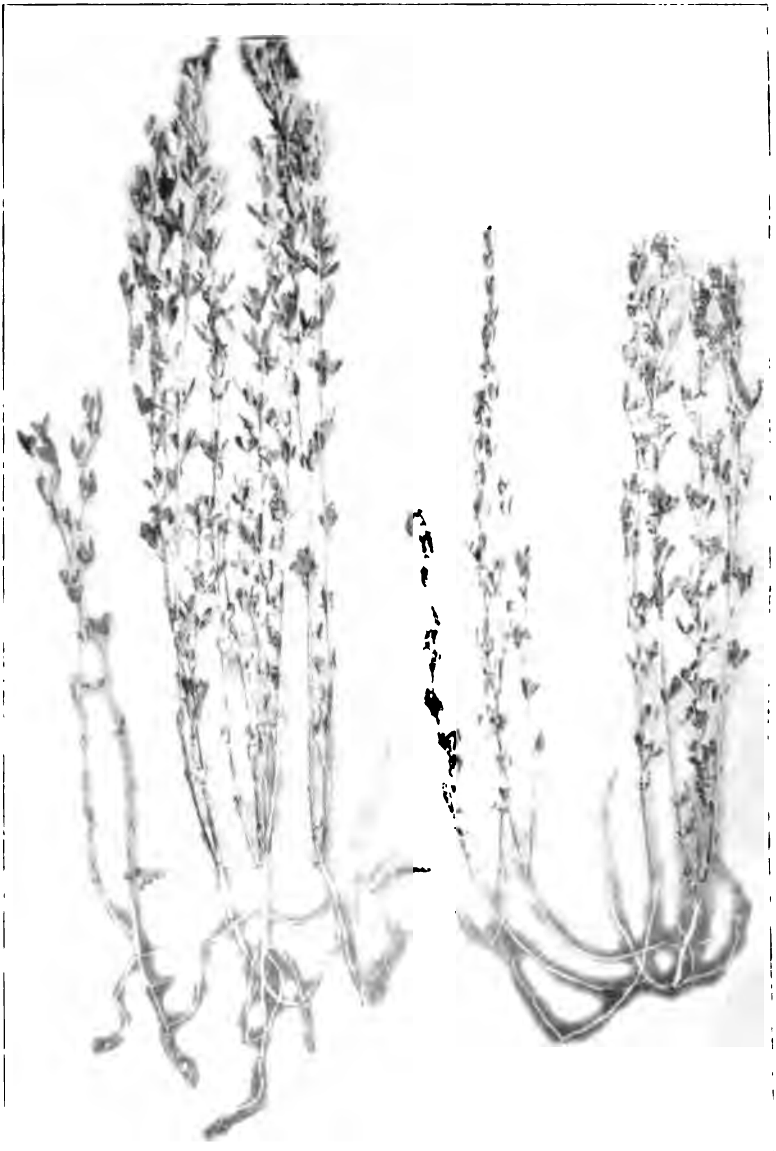
The seed should be sown from one-half to two inches deep. Because of the danger of the surface drying out I think it advisable to plant as deep as may be done with safety. This will vary somewhat with the kind of soil, but in general if planted more than three inches deep there is danger that the germinating plant will not be able to reach the surface. We have lost our seed once or twice by planting too deep.

A point of great importance is that the soil should be packed around the seed. Many failures to secure a stand of alfalfa are traceable to sowing the seed broadcast on newly plowed ground and harrowing to mix the seed loosely with the surface soil. Under favorable conditions of soil and moisture, alfalfa may be so grown, but sowing broadcast is hazardous at the best. Where sown broadcast from one-half to one-third more seed must be used to secure the same stand, as a large percent of it is either not covered at all or so lightly covered that it fails to grow. Alfalfa seed has been worth from six dollars to twelve dollars per hundred pounds for the last ten years. This means that from one-half to two or three dollars' worth of seed is thrown away on each acre of land where sown broadcast and harrowed in. If a seed drill can not be obtained, and it is necessary to broadcast, it should be thoroughly harrowed in, then rolled and lightly harrowed again. Undoubtedly the best machine for sowing alfalfa (and for that matter any other small seed in our soils), is some form of the press drill which distributes the seed evenly and presses the soil firmly around it. Thus the seed is planted to the right depth, and the moisture of the soil is brought in contact with it, which insures germination and growth. We feel that too much can not be said in favor of the press drill. If a ranchman had fifty or one hundred acres to sow to alfalfa or if he sows any amount of grain, sixty or seventy dollars for one of these drills would be a paying investment.

At the start it is well to expect to take two years to get a good stand of alfalfa and bring it into producing condition. The second spring the meadow or at least parts of it should be resown unless a uniformly good stand is secured over all the land the first year.

AMOUNT OF SEED.—The amount of seed to sow depends on local conditions, the kind of seed purchased and the purpose for which it is to be grown. Two kinds of seed may be obtained on the market. First quality seed should be heavy and plump, clean, of uniform size and color. "Second" is lighter seed, usually obtained from fanning and screening when the seed is threshed, contains much under ripe, green colored, shriveled grain and may not be free from weed seeds. For higher altitudes at least only the best seed should be purchased. Where the soil and climate are most favorable and the plants become sufficiently strong to withstand weeds during the summer and the cold of the first winter, second quality seed may do well enough, though it is always safe and advisable to get the best. About twice as much seed should be sown where the crop is to be raised for hay as would be used if it is intended to raise seed. We doubt if it will pay to raise alfalfa seed in Wyoming where the altitude is above 6,500 feet, as the season is short and the yield of ripened seed would be very small. For hay we believe in heavy seeding.

The thicker the plants are on the ground the better the yield and the finer will be the stems, which makes the



Alfalfa with and without Nurse Crop. Large plants show growth first season from seed sown alone. Small plants grown with Oats. Wyoming Experiment Station.

hay of better quality. The best plat of alfalfa raised on the Experiment Farm at Laramie was sown with forty pounds of seed per acre. This amount is excessive, however, and more than need be sown to secure the best results. From twenty-five to thirty pounds per acre should be sown the first year and if the stand is thin five or ten pounds may be sown over it the next year. Where the growth is thick in some places and thin in others, only the thin spots need be resown the second year.

SOWING WITH VS. WITHOUT NURSE-CROP.—A common practice is to sow alfalfa with some other crop, usually oats. The claim has been made that the young alfalfa plants are shaded and protected by the oats so they become better established than when planted alone, and of course a crop of oats is obtained at the same time. Where alfalfa is planted alone, small or no return is made from the land the first season after planting. However, the nurse crop does retard the growth of the alfalfa, because it robs the small plants of a large amount of moisture and sunshine. At low altitudes, where alfalfa is perfectly hardy and will make a crop on any soil under almost any kind of treatment, it may be planted with light seeding of oats, barley or wheat. Where there is any difficulty or question about establishing an alfalfa meadow the nurse crop should not be used. To determine the effect of planting with or without a nursecrop, some experiments, have been carried out at Laramie. In 1897 a plat was divided in two parts, one of which was sown to alfalfa with a nursecrop of oats and the other without oats. Sixteen pounds of alfalfa seed per acre was used on each portion of the plat. Our illustration made from a photograph of average plants taken from each part of the plat in the summer shows the difference in growth the first season. The plants were more thrifty, larger and stronger where grown alone. Table I gives the results in yield per acre for 1898 and 1899.

TABLE I.—*Alfalfa with and without Nurse Crop. Laramie.*
Sown 1897.

	1898			1899			Average Yield Two Years		
	Date	Sown with Oats	Sown without Oats	Date	Sown with Oats	Sown without Oats	Sown with Oats	Sown without Oats	Gain in Hay in Two Years
		lbs	*lbs.*		*lbs*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
First Crop . . .	July 14	2557	4100	July 21	2596	2856	2576	3478	1803
Second Crop . .	Sept. 8	2842	3713	Sept. 11	1940	2040	2391	2576	971
Total.	. . . . . .	5399	7813	. . . . . .	4536	4896	4967	6054	2774
Gain	. . . . . .	. . .	2414	. . . . . .	. . .	360	. . . . .	1087	. . . .

This shows that the effect of sowing with the oats was felt by the alfalfa for three years after planting and reduced the average yield over one-half ton per acre, while in the two seasons nearly one and one-half tons per acre more hay was obtained from the plat on which alfalfa was sown alone. At Laramie prices it is doubtful if the oats secured would be worth as much as the value of the hay from the two succeeding crops of alfalfa, and they certainly would not pay if the injurious effects are more lasting than this in the alfalfa meadow.

In 1899 two other plats were planted with and without a crop of oats. They were planted June 15, using about twenty pounds of alfalfa seed per acre. The plat planted without oats was cut on September 11 and yielded 1,187 pounds of cured hay per acre. The hay contained a little volunteer grain and there was an occasional stalk of alfalfa from a previous seeding which increased the yield somewhat. The plat sown with Cape oats was harvested

August 18 and yielded 2,778 pounds of straw and grain per acre from which was threshed 792 pounds of oats. A fine stand of alfalfa was obtained on this plat which grew from one to two inches higher than the oat stubble in the fall. There was not so much apparent difference in the growth of alfalfa on the two plats as noted in 1897, but the final results can not be reported until more crops of alfalfa can be harvested. It should be said that the Cape oat is a very early variety which produces short straw and few leaves. It shades the alfalfa much less than the coarser strawed varieties and being cut early gives the alfalfa time to recover strong growth in the fall. It is not a heavy yielder but is very early, produces a short, quick growth and can be recommended for localities with short season and for planting with alfalfa where it is desired to grow it with a nurse crop.

WHEN TO CUT AND HOW TO CURE—Alfalfa should be cut when budded or just before it has reached full bloom. Experience in other places shows that the hay contains more nutriment at this time than before budding or after blooming. If allowed to go to seed the stems become coarse, hard and woody and lose many of the lower leaves. After cutting the plants grow rapidly and where the season is long may be harvested three or four times. With short seasons above six thousand feet altitude it will usually not be cut more than twice and on the Laramie Plains only the first cutting produces a full crop. The value of the hay depends much on the method and care used in curing it. Alfalfa can not be cured the way native hay is usually handled. After cutting it should be allowed to lie in the swath only long enough to become well wilted, when it should be raked into windrows where it may be left a few hours or a day before putting into cocks. Many rake in the evening what was cut in the morning of the same day. It should not be left long enough to become dry and brittle or many of the leaves will rattle off in raking, which reduces the value of the hay. Many use the rake for bunching the hay from the windrow, but it leaves the hay in loose, rough, tangled masses difficult to handle or manage if large, and the curing is not so well done as when the hay is made into cocks with the fork. Unless press of work or lack of help makes it necessary to bunch with the rake, cocking the hay by hand with the fork is to be recommended. The principal part of the curing is done in the cock, and when well done the hay does not lose its leaves, retains its beautiful green color, and will not must or spoil in the stack. Some experience and good curing weather are necessary to insure the hay being in the most perfect condition when it comes out of the stack. While perfection is difficult to attain there is little difficulty in obtaining a good quality of hay.

To show the amount of water lost in curing, we weighed the hay from one hundred square feet on acre plat 8, and again weighed it when fully cured and ready to go into the stack in 1895. The yield of green hay was at the rate of 24,874 pounds per acre, and of cured hay 6,540 pounds per acre, showing a loss of 73.7 per cent in weight before it went into the stack. Shrinking undoubtedly goes on for some time after stacking.

ALFALFA AS A HAY CROP.

The feeding value of alfalfa is recognized wherever it has been grown. Its composition and digestibility have been determined in many places and its nutritive and fattening qualities have been demonstrated in a practical way in every land since the Romans fed it to their horses. More study of its value compared with other fodders in our state will give more complete information than is possible for us to report at this time. We know something of its value, limitations and management from our own experience. The Station has carried out some experiments in stock feeding with alfalfa at Lander. The results of our first feeding trials there with cattle and sheep are reported in Bulletin No. 30 of this Station. In a later experiment which has not yet been reported cows were fed with alfalfa alone, with the best timothy hay, and with timothy and alfalfa mixed. Those fed alfalfa alone made larger gains than those given other hay. Some trouble was experienced with the alfalfa bloating the stock when allowed to eat all they would of the hay. Mr. Meyer, the Superintendent, attributed the trouble to close confinement of the stock, as he had experienced no difficulty with alfalfa where his cattle could exercise in the open.

The tendency of cattle and sheep to bloat on alfalfa, both in the green state when pastured or in the dry state when the hay is carelessly fed to stock not accustomed to it, is well understood and some caution and judgment must be exercised to avoid accidents of this kind which may result seriously. The writer has had experience in feeding alfalfa for many years and has never personally observed a serious case of bloating from feeding the dry hay. However we have known of others losing cows from such bloating but undoubtedly, in every case, it could have been prevented. It usually occurs when animals which have not been accustomed to alfalfa hay are fed all they can eat of it when hungry, or perhaps when both hungry and thirsty, and then allowed to drink freely when their stomachs are distended with hay. Alfalfa is one of the most palatable fodders and animals which are hungry or those which naturally have greedy appetites, as Jersey cows, will gorge themselves with it if allowed to do so. Such animals should be fed sparingly until they become used to the diet, allowing plenty of exercise. If the animal does become seriously bloated from eating either the green or dry alfalfa, the timely use of the trocar will always save their lives. There is some difference between the different cuttings of alfalfa in its tendency to bloat cows. The first cutting is considered the best hay for horses and will not bloat cattle as readily as will cuttings made later in the season, though many now prefer second or third cutting for milch cows. At Laramie the first crop will cure in much shorter time than is required for the last cutting. The plants are less succulent and mature better in the first half of the season.

Poorly matured alfalfa when put into the stack too green or wet will become musty the same as other clovers. Feeding this hay to horses gives them a disease which farmers often call "heaves." True heaves is probably due to overfeeding such fodders while the trouble under consideration is undoubtedly a bronchial affection due to irritation produced by the dust. The animals soon recover as a rule when the dusty hay causing it is replaced by clean food.

Much interest is taken in the subject of pasturing alfalfa. Its use as pasture can be recommended for horses and swine, especially for the last named animals. The careful farmer who gives the subject intelligent personal attention may succeed in pasturing cattle and sheep on alfalfa without serious losses but our advice is to never use such fields for cattle and sheep pasture. It is dangerous to the stock and injurious to the alfalfa. On the Laramie Plains, and no doubt the statements are true for all high altitudes, at least, the young plants are not strong enough to stand long continued pasturing the first year after sowing the seed, and we believe much tramping injurious at any time. The alfalfa field has a hay producing power which gives it a value sufficiently great without trying to overdo the matter by pasturing it the remainder of the year. If cattle are allowed access to the growing alfalfa, however, it should be remembered that danger of bloating is especially great when the stock is first turned in the meadow, when the dew is on the plants, or during wet weather, or when the plants have been frosted. The farmer who takes these risks should ever have his trocar or sharp knife ready to save the life of his animals by puncturing the stomach to let out the accumulated gas. The difficulties we have mentioned are such as are experienced in Eastern states with clovers. They may be overcome by proper care and management and should not deter the farmer from growing and making profitable use of this plant.

YIELDS OF ALFALFA OBTAINED IN CROPPING EXPERIMENTS.

The yields we have obtained on the Experiment Farms will indicate the cropping qualities of alfalfa in the localities where it has been grown. The yield of hay produced at Laramie is of especial interest, as it shows the advantage of alfalfa over native hay at this altitude. It should be said that native grass will probably not produce an average of more than a ton of cured hay per acre, though it may yield as much as two tons or more in favored localities. Often the amount obtained is only a fraction of a ton per acre. One year on the Experiment Farm we obtained as much hay from a single acre of alfalfa as was produced on thirty acres of irrigated native meadow on an adjoining field. The native meadow here referred to was a very poor one and not worth cutting, but such results are often obtained the first year or two after irrigating to make them produce hay. That an idea of our average results may be obtained we report the yields from each field separately and of each cutting for the number of seasons the alfalfa has been grown.

TABLE II.—*Acre Plat 8. Alfalfa at Laramie. Area, 0.52 acre.*

Year	First Crop		Second Crop		Total Yield per Acre
	Date Harvested	Yield per Acre	Date Harvested	Yield per acre	
		lbs.		*lbs.*	*lbs.*
1895	Aug. 6	5019	Sept. 24	2557	7576
1896	July 7	1641*	Sept. 8	3040	4681
1897	July 16	3860	Sept. 9	3860	7720
1898	July 14	4759	Sept. 8	3909	8668
Average yield per acre. . .	. . . .	3820	. . . .	3341	7161

*Only partial crop, as it was injured by hail.

Acre plat 8 was planted in 1893 but failed to make a stand. Was given 12 loads manure per acre in winter, plowed up in spring of 1894 and resown at the rate of 40 pounds seed per acre. Crop produced in 1894, first year, from seed, was 1967 pounds per acre. For irrigation of this plat, see No. 2 in Table XV, on Duty of Water, Page 80.

TABLE III.—*Acre Plat 18. Alfalfa at Laramie.*
Area, 0.96 acre.

Year	Fisrt Crop		Second Crop		Total Yield per Acre
	Date Harvested	Yield per Acre	Date Harvested	Yield per Acre	
		lbs.		*lbs.*	*lbs*
1897	July 16	1513	Sept. 9	2587	4100
1898	July 8	3865	Aug. 31	3182	7047
1899	July 24	2430	Sept. 11	1273	3703
Average yield.	. . . .	2603	. . . .	2347	4950

Plat 18 was planted in spring of 1896 at the rate of 30 pounds of seed per acre. The alfalfa made only a short growth the first season, but was cut in the fall, largely to remove the weeds which had grown with it. As it consisted largely of weeds, the hay was not weighed to obtain the yield.

TABLE IV.—*Acre Plat 27. Alfalfa at Laramie.*
Area, 0 5 acre.

Year.	First Crop		Second Crop		Total Yield per Acre
	Date Harvested	Yield per Acre	Date Harvested	Yield per Acre	
		lbs.		*lbs.*	*lbs.*
1898	July 18	4848	Sept. 8	2985	7833
1899	July 24	3502	Sept. 11	2704	6206
Average yield	. . . .	4175	. . . .	2844	7019

Plat 27 was planted in 1897 at the rate of 18 pounds seed per acre, with nurse crop of oats. On May 12, 1898, a few thin spots were resown.

TABLE V.—*East Field. Alfalfa at Laramie.*
Area, 3.87 acres.

Year	First Crop		Second Crop		Total Yield per Acre
	Date Harvested	Yield per Acre	Date Harvested	Yield per Acre	
		lbs.		*lbs.*	*lbs.*
1898	July 15-16	289*	Sept. 9	1132	. . . . . .
1899	July 10	3005	Sept. 13	2314	5319

*About one-fourth of the field cut. The rest was from the same season's planting and too small to harvest. This yield is based on entire area of field sown.

The east field was planted in 1897 at the rate of 20.6 pounds of seed per acre. It was sown with nurse crop of oats. Only a part of it grew, and nearly all of the plat was resown in 1898, using at the rate of 20 pounds of seed per acre.

Acre Plat 16.—Alfalfa at Laramie—Turkestan and common form. For report see Table XIII, Page 72.

Acre Plat 15.—Alfalfa at Laramie, sown with and without nurse crop. For report of yields, see Table I, Page 58.

Acre Plat 2.—Alfalfa at Laramie—On alkali ground. For report of yields, see Table XIV, Page 75.

Acre Plat 17.—Alfalfa at Laramie. North part of plat, area 0.70 acre, planted June 15, 1899, at rate of 20 pounds seed per acre, without nurse crop; was cut Sept. 11 and yielded at the rate of 1187 pounds hay per acre. The plants did not make a large growth, but contained some volunteer grain and an occasional plant of old alfalfa, which increased the yield somewhat.

Acre Plat 17.—South part of plat, area 0.25 acre, was planted May 12, 1899 at rate of 20 pounds seed per acre, with a nurse crop of oats. The oats were harvested Aug. 18, after which the alfalfa grew from one to two inches higher than the oat stubble. A good stand of alfalfa was secured on both parts of the plat.

Acre Plat 33.—Alfalfa at Laramie. Area, 0.46 acre. Planted in spring of 1899 by drilling with timothy on stubble ground. The timothy failed to grow. The alfalfa made good growth for the first season. It was cut on Sept. 11 and yielded at the rate of 1766 pounds per acre.

Alfalfa on new sod land, Laramie.—Area, 5.4 acres. Planted in spring of 1899 at the rate of 18 pounds seed per acre with 38 pounds oats per acre. A good stand of alfalfa was secured, but it did not make large growth.

ALFALFA CROPS AT ALTITUDES BELOW 6,000 FEET.—We have a few records of alfalfa yields at Lander, Sheridan and Wheatland, where sub-station farms were located. In 1895 I examined the alfalfa at Sundance, which has been planted since the experiment farm was established in 1891. The plants were small, weak and thinly scattered, having more the appearance of the first year's growth than of having been established four or five years. The Sundance farm depends on the rainfall, which ranges from 17 to 20 inches per year. It is doubtful if alfalfa will succeed in that region.

The following tables give the results at Lander of which we have reports. The Lander farm is located at an altitude of about 5,500 feet.

TABLE VI.—*Acre Plat 45. Alfalfa at Lander.*
Planted in 1891.

Year.	First Crop		Second Crop		Total Yield per Acre
	Date Harvested	Yield per Acre	Date Harvested	Yield per Acre	
		lbs.		*lbs.*	*lbs.*
1892	Aug. 8	. . . . . .	Oct. 5	. . . . . .	8000
1893	July 17	3000	Sept. 13	4000	7000
1894	Oct. 1	Cut for seed,	yield 312 lbs	seed per acre	
1895	Sept. 28*	Cut for seed,	yield 240 lbs	seed per acre	

*The plat was accidentally irrigated on August 20, which caused a second growth of seed that did not ripen and reduced the yield.

TABLE VII.—*Acre Plat 8. Alfalfa at Lander*
Planted May 15, 1893.

Year	First Crop		Second Crop		Total Yield per Acre
	Date Harvested	Yield per Acre	Date Harvested	Yield per Acre	
		lbs.		*lbs.*	*lbs.*
1893	Sept. 12	1000	. . . . . .	. . . . . .	. . . . . .
1894	. . . . . .	3500	. . . . . .	1500*	. . . . . .
1885	July 5	5000	Sept. 11	3000	8000

*This crop was badly injured by the Utah crickets, which devoured everything in their path.

SHERIDAN.—The Sheridan farm is located at an altitude of about 4,000 feet. The soil is clay underlaid with hard pan, but alfalfa makes remarkable growth and yields.

No doubt it will do better on other farms near Sheridan where the soil is deeper. We have but few reports of crops raised. In 1896, acre plat 5 was planted to alfalfa. It was cut August 1 to kill the weeds, and Sept. 10 the first year it yielded 1200 pounds per acre. In 1897, on June 21, 3700 pounds of hay per acre were obtained, but no other reports were made on the plat. The following table gives the results on the only other field reported.

TABLE VIII.—*Acre Plat 30. Alfalfa at Sheridan.*
Planted May 24, 1894.

Year	First Crop		Second Crop		Third Crop		Total Yield
	Date	Yield	Date	Yield	Date	Yield	
		lbs.		*lbs.*		*lbs.*	*lbs.*
1894.	Aug. 2*	......	Sept. 24	1500	......	......	......
1895.	June 26	......	Aug. 21	......	......	......	10600
1896.	June 25	6800	Aug. 10	6000	Sept. 28	4000	16800
1897.	June 20	6430	Aug. 11	6200	Oct. 3	1800	14430

*Cut to kill the weeds.

WHEATLAND.—The sub-station farm at Wheatland was located at an altitude of about 4,700 feet. The soil is a deep sandy loam and the season is long. The alfalfa is usually cut three times and large yields are secured. Several fields of alfalfa were grown to improve the land for other crops, usually being plowed under when green, the fall of the year it was planted. In 1895, Plat 1 was sown with alfalfa for the purpose of plowing under as a green manure. It made such rapid growth that it was harvested on July 22 and yielded 2,400 pounds hay per acre. The second crop was plowed under. The same year, 1895, Plat 2 was treated in the same manner. The first crop yielded 2,540 pounds per acre. Plats 7, 8 and 9 were treated the same and yielded at the first cutting 2,100 pounds, 2,600 pounds and 2,450 pounds per acre, respectively. The following tables give the results with fields on which the alfalfa was allowed to grow more than one year:

TABLE IX.—*Acre Plat 19. Alfalfa at Wheatland.*
Planted June, 1891.

Year	First Crop		Second Crop		Third Crop		Total Yield per Acre
	Date	Yield	Date	Yield	Date	Yield	
		lbs		*lbs.*		*lbs.*	*lbs.*
1892.	July 6	6500	Aug. 3	5400	Sept. 26	3850	15750
1893.	July 5	6680	Aug. 9	4872	Sept. 16	4200	15752
1894.	June 23	8000	Aug. 6	7000	Sept. 17	4352	19352
1895.	Cut for	seed, yield	181 pounds	seed per	acre.		
1896.	Left for	seed	but was	injured by	hail June	21st.	
Average, first 3 yrs		7060		5757		4134	16951

TABLE X —*Acre Plat 12. Alfalfa at Wheatland.*
Planted in 1894.

Year	First Crop		Second Crop		Third Crop		Total Yield per Acre
	Date	Yield	Date	Yield	Date	Yield	
		lbs.		*lbs.*		*lbs.*	*lbs.*
1895	June 28	7832	Aug. 16	7620	Sept. 18	4950	20402
1896	June 18	5880	Aug. 3	4500	*	. . . . .	10380

*Owing to shortage of water for irrigation in 1896, only two crops were obtained.

TABLE XI.—*Acre Plat 17. Alfalfa at Wheatland.*
Planted in 1894.

Year	First Crop		Second Crop		Third Crop		Total Yield per Acre
	Date	Yield	Date	Yield	Date	Yield	
		lbs.		*lbs.*		*lbs.*	*lbs.*
1895	June 28	4312	Aug. 16	4500	Sept. 18	2540	11352
1896	June 20	6720	July 29	4750	*	. . . . .	11470

*No third crop reported, probably for same reason as that given under Acre Plat 12.

TABLE XII.—*Acre Plat 26. Alfalfa at Wheatland.*

Planted in 1892. (?)

Year	First Crop		Second Crop		Third Crop		Total Yield per Acre
	Date	Yield	Date	Yield	Date	Yield	
		lbs.		*lbs.*		*lbs.*	*lbs.*
1893	July 5	3422	Aug 9	4112	Sept. 16	3000	10534
1894	*	. . . . .	Left for	seed. Pro	duced 122	lbs seed	per acre.
1895	June 28	5214	Left for	seed.**	. . . . .	. . . . .	. . .

*First crop destroyed by army worms. (Species not known.)

**After first cutting was left for seed. At time of frost, on Sept. 21, about one-half the seed was mature. The crop was not harvested.

TURKESTAN ALFALFA.

(*Medicago sativa Turkestanica.*)

The seed* of this new variety of alfalfa was imported by the U. S. Department of Agriculture and a small amount was sent to this Station for trial in the spring of 1895 A small plat 12x99 feet was planted with it, by sowing broadcast, the first week in June. Two pounds of seed were used on the plat. It came up June 10th, making a thick stand, and made a growth of about four inches the first season. Little attention was given the crop in 1896 and the yield of the single cutting made was very small. The crop looked promising in 1897 and was left to grow as long as possible with the hope that it would ripen seed. It was planted so thickly, however, that the seed failed to ripen.**

It was not cut till after frost had stopped its growth and the yield obtained was only ordinary for a single cutting. If it had been cut twice or earlier in the season the yield would undoubtedly have been much better. Some botanists have claimed that the Turkestan alfalfa differs from the species in having more hairy leaves and making smaller growth, but we have been unable to detect any botanical difference whatever. A stem of each variety was shown a Botanist who thought he knew the difference and he was unable to say which was common alfalfa and which the new variety. Its growth appeared the same to us and we gave it little attention until the severe winter of 1898-99 put it to the test. On all parts of the farm plats of alfalfa showed more or less winter killing, but to all appearances not a single plant of the Turkestan variety had been killed. We find that it has also shown its hardiness in other places and we no longer doubt its superior cropping qualities. Not only does it seem to be hardier but under our conditions it has produced larger yields than the old variety, when planted side by side, and given the same treatment. in time and amount of irrigation and method of handling. Its difference from the common form seems to be in constitution and hardiness or from favorable results due to change of seed. No doubt both of these conditions have their influence on its success in this country and gives the variety greater value, especially for our high altitude.

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*Since the Secretary of Agriculture reported our success with Turkestan alfalfa we are receiving many inquiries for the seed from farmers all over the United States. The seed can not be obtained in this country, as no one has yet raised it for market. Prof. Jared G. Smith of the Division of Botany, in the U. S. Department of Agriculture, has told me that the Department is making an attempt to import more of this seed for distribution in small amounts.

**Mr. A. H. Danielson, an assistant in this department, who was then an agricultural student in the University, was given a small handful of the seed which was furnished us by the Department. He took it home and threw it in the back yard. It came up and has since ripened a little seed, which he has kindly offered us. With it we hope to make a thin planting which will produce more of the seed for future use.

Our results with Turkestan alfalfa are given in Table 13, in which we have also compared the crops produced from a plat of the ordinary form which was planted near it for comparison. Averaging the results for the last two seasons, 1898 and 1899, when they have been cut for hay and cured alike, shows the superior cropping qualities of the new variety, which produced over three-fourths of a ton more hay per acre. For amounts of water used on these plats in irrigating in 1899, see No. 10 in Table XV, Page 80, on Duty of Water.

TABLE XIII.—*Acre Plat 16. Turkestan Alfalfa and Common Form. Laramie.*

Year	Turkestan Alfalfa. Planted 1895.					Common Alfalfa. Planted 1896.				
	Date of First Cutting	Date of Second Cutting	Yield First Crop per acre	Yield Second Crop per acre	Total Yield per acre	Date of First Cutting	Date of Second Cutting	Yield First Crop per acre	Yield Second Crop per acre	Total Yield per acre
			lbs.	*lbs.*	*lbs.*			*lbs.*	*lbs.*	*lbs.*
1896	Sept. 21	....	912	...	...	....	....	...	...	...
1897	Sept. 9	....	3302*	...	...	Aug. 6.	Sept 9	3240	2340	5580
1898	Aug. 3	Sept. 15	6446	943	7389	Aug. 3.	Sept. 15	5580	900	6480
1899	July 20	Sept. 11	4717	3145	7862	July 20	Sept. 11	3660	2520	5580
Average last two years	....	....	5581	2044	7625	....	....	4620	1710	6030

*Cut at time of frost.

Alfalfa Common variety, showing Height of Second Crop. Laramie, 1899.
Wyoming Experiment Station.

Turkestan Alfalfa. Second Crop. Laramie, 1899. Wyoming Experiment Station.

WINTER KILLING OF ALFALFA.

Only general statements will be made here regarding the killing of alfalfa plants during the winter. So far as we have observed, the trouble is no more apt to occur at high altitudes on the Laramie Plains than it is at lower altitudes in other parts of the state. The trouble reported from Wheatland and other localities has been more extensive than any we have experienced at Laramie.

Little is positively known of the cause of winter killing of alfalfa. Apparently it is due to hard freezing when the ground is very wet. If water is run on the plants just before hard freezing there is danger that they may be killed. In places where heavy snow fall melts during the day, and the surface of the soil becomes thawed out, so the water runs into the soil around the crown of the plant and freezes, the alfalfa crown will die and will be found in the spring in a soft, mushy or decayed condition. Ice may form over the alfalfa, or snow cover it all winter without injury to it, but if ice does no damage it is probably due to the ground being frozen before the ice is formed over the surface and the crowns of the plants, which are usually below the soil surface, do not come directly into contact with freezing water. In the opinion of the writer winter killing is generally due to free water freezing around the crown of the plant. Whether the freezing of the water in the plants ruptures the cells or not has not been determined. During dry, open winters little or no alfalfa which has been growing long enough to become well established is lost unless it be in low, wet places. As shown elsewhere in this bulletin, the Turkestan alfalfa seems better able to live under adverse conditions than the form commonly grown, but with proper precaution in locating the alfalfa field and care in handling it, winter killing is not a serious trouble with us. The spring of 1899, after the unusually hard winter, was the only time we have observed any extensive winter killing on the Experiment Farm. The writer's opinion in regard to its cause is the result of studying these instances along with observations in other places.

ALFALFA AND ALKALI SOILS.

Alfalfa is one of the most valuable plants to sow on low parts of the farm which may become useless through the rise of alkali from below, at least if this land has such drainage that the free ground water does not stand nearer than two or three feet from the surface. Alfalfa stands the white alkali comparatively well, shades the ground, which prevents rapid evaporation from the soil surface, and sends its roots deep into the lower soil to feed. We have reported on the germination and growth of alfalfa in several experiments which indicate its usefulness for such soils.* It is true, however, that in places which accumulate large amounts of alkali the free soil water usually comes near the surface for a part of the year at least. Whether the soil water contains alkali salts in solution or not, if it stands near the surface alfalfa will soon die, and much less salt evidently has deleterious effect in such places.

In 1897 we planted alfalfa on an acre of land which was near that already destroyed for ordinary crops by the rise of salts to the surface. A part of the land had failed to grow a crop of oats planted with the alfalfa as a nurse crop, and where the oats had failed to grow the alfalfa had a sickly appearance. A good stand of alfalfa was secured. In 1898 the acre yielded two and three-fourths tons of hay. On the lower part of the plat the alfalfa began to die that year and nearly one-half the total area has become unproductive. The yield of hay in 1899 fell to a little over one and one-half tons. The following table gives the crops produced on this land:

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*See Bulletins Nos. 29 and 39, and Ninth Annual Report, Wyoming Experiment Station.

TABLE XIV.—*Acre Plat 2. Alfalfa on Alkali Land. Laramie.*
Area .96 acre.

Year	First Crop		Second Crop		Total Yield per Acre
	Date Harvested	Yield per Acre	Date Harvested	Yield per Acre	
		lbs.		*lbs.*	*lbs.*
1898	July 14	3156	Sept. 8	2356	5512
1899	July 20	1853	Sept. 12	1335	3188
Average yield for two years .	. . . . . .	2504	. . . . . .	1845	4350

Acre plat 2 was planted in the spring of 1897 at rate of 16 pounds seed per acre, with a nurse crop of oats. On May 11, 1898, the entire plat was resown. From one-third to one-half the entire plat has become unproductive through the killing of the plants by alkali, but above yields are taken for the area of the land sown. For irrigation of this plat in 1899, see No. 9, in Table XV, Duty of Water, on Page 80.

Professor Slosson has kindly analyzed four samples of soil taken from this plat to show the strength of alkali which has killed the alfalfa and the strength of salts in the part of the plat on which the plants are still in a thrifty condition.

The following amount of salts were found in the samples taken:

	Percent.	Percent of Sodium Chloride.
Alfalfa Killed.		
Total salts in first six inches of soil.	0.620	0.029
Total salts in soil from six inches to one foot deep . .	0.792	0.053
Alfalfa Thrifty.		
Total salts in first six inches of soil.	0.034	0.000
Total salts in soil from six inches to one foot deep . .	0.270	0.003

The Sodium Chloride is reported separately, as it is more injurious than the sulphates, which probably make up about three-fourths of the total salts.* The result probably corresponds closely to the estimate made in Bulletin No. 39 of this station,** in which we expressed the belief that alfalfa would grow in the presence of as much as one per cent of our ordinary white alkali (Sulphate of Soda and Magnesia) in two inches of surface soil, providing the water level is not nearer the surface than two or three feet. We suspect the water level is dangerously near the surface in the above plat during a portion of the irrigating season, and has had its influence in destroying the plants which have died.

It is very doubtful if alfalfa will grow on any land upon which there is a white incrustation of salts during any part of the year, unless the drainage is such that the salts may be washed out by flooding with irrigation water. Soil which becomes incrusted with salts is too strong with alkali for any plants except the most resistent species, and our experience indicates that it should never be selected for the production of an alfalfa meadow. In many places on the Laramie Plains there are soils which are either too wet or contain too much alkali for alfalfa and it is hoped calling attention to the matter here will prevent many farmers from the loss of labor and seed by attempting to grow it in such places.

IRRIGATION OF ALFALFA.

Although alfalfa is so hardy and will live through long periods of drouth it will not produce hay unless irrigated. It is of vital importance to apply water at the right time and conduct the irrigation in the right way. Flooding as the native meadows are flooded for long periods of time is much more quickly fatal to alfalfa than it is to our best native grasses. It will not do to turn the water on and look at it once a week to see that it is still running. Alfalfa soon dies if its feet are kept wet, and it needs long breathing spells and warm growing weather. Where the irrigating water is cold it produces a chilling effect, and the irrigation should be done quickly and the water turned off as soon as the ground has become thoroughly wet. The best time to irrigate alfalfa is immediately after the hay has been removed. Some irrigate just before the hay is cut, but our observations indicate that much better results are obtained by irrigating after cutting. If the weather is very dry, light irrigations may be needed between the cuttings. We believe in irrigating in the fall, some time after the last cutting has been made, to keep the soil from becoming too dry during the winter. It should not be done so late, however, that the ground is apt to freeze hard while very wet, as this seems to be the principal cause of winter killing. Too much water is fatal either in the summer or winter. On the Experiment Farm one season we irrigated one-half of a field of alfalfa as late as October, leaving the other half without water. The part irrigated started earlier the next spring and up to the time of the first cutting the dividing line between that which had not been irrigated and that which was watered late in the fall was distinctly visible, as the hay grew two or three inches higher on the fall irrigated portion.

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*For composition of alkali from this portion of our farm according to previous analyses, see Bulletin No. 29, page 223.

**Wyoming Station Bulletin No. 39, page 47.

DUTY OF WATER ON ALFALFA.—By duty of water we mean the amount which is used on the land. Alfalfa is a perennial plant which occupies the land all the time. Its growing season is long and that it requires a proportionally large amount of water would be expected. Table XV gives the results of fifteen measurements of water on alfalfa made by the Experiment Station. All these measurements were made on the Experiment Station Farm at Laramie, except No. 1, which was made at Wheatland in 1893. (For record of the cropping on this plat, see Table IX, Page 69.) In this table the duty is expressed in the number of cubic feet of water used on each acre of land; in the depth to which the water used would cover the land, or as the records are reduced to the acre standard this depth represents the number of acre feet used for each acre;* in the number of acres which one cubic foot per second continuous flow would irrigate if used at the same rate as on these crops and allowed to run four months or 123 days, and also if allowed to run only 95 days. Ninety-five days very nearly represents the irrigating season for alfalfa at Laramie, though four months is nearer the length of the growing season.

As the amount of rainfall has such an important bearing on the amount of water needed in irrigation, we have added two columns, one of which shows the depth to which the water used in irrigation and that supplied as rain during the growing months of May, June, July, August and September covered the land, and the other shows the total amount of water coming to the land during the entire year by both irrigation and rainfall. The table shows that we have not used very large amounts of water in the production of alfalfa. Our measurements of water used on native hay show that only about one-half as much water was used on alfalfa as on the native hay, and undoubtedly the difference between the two kinds of hay will be found to be as great as this. An average of the fourteen measurements which have been made at Laramie shows the depth of water applied to alfalfa to be 2.22 feet. An average of six measurements on oats, wheat and barley made before 1899 shows 2.74 acre feet applied to each acre of those crops. The only class of plants on which less water has been used than on the alfalfa have been root crops. An average of seven measurements of the irrigation water used on potatoes, turnips, and sugar beets at Laramie before 1899 shows the depth applied to be only 0.98 feet.

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*An acre foot is the amount required to cover one acre one foot deep, or 43,560 cubic feet.

The following table gives the number of times each field of alfalfa was irrigated, the date of each irrigation and the amount of water applied each time in cubic feet per acre, and the depth to which it would cover the land.

TABLE XV.—*Duty of Water on Alfalfa.*

No.	Year	Area	Date Planted	No. of Irrigations	Water received by Irrigation per Acre		Depth of Water Supplied by Irrigation and Rainfall in yr.	Depth of Water received by Irrigation and Rainfall in growing season*	Duty of 1 sec. ft. for season of 4 months	Duty of 1 sec. ft. for season of 95 days	Yield per Acre	Remarks.
					Quantity	Depth over surface						
		acres			*cu. ft.*	*ft.*	*ft.*	*ft.*	*acres*	*acres*	*lbs.*	
1	1893	1.	1891	6	113,184	2.60	3.13	2.71	93.8	72.6	15752	At Wheatland. Three crops.
2	1896	.52	1894	2	47,356	1.08	1.98	1.69	224.5	173.3	4664	Laramie. Two crops.
3	1898	1.	1898	4	129,388	2.97	3.61	3.35	82.0	63.4	2220	Laramie. First year.
4	1898	3.9	1894	5	113,101	2.60	3.24	2.98	94.0	72.6	8668	Laramie. Two crops.
5	1899	3.87	1897-98	4	135,365	3.11	4.02	3.53	78.5	60.7	5319	Laramie. [nurse crop.
6	"	.95	1897	3	84,063	2.14	3.05	2.56	125.5	97.0	5510	Laramie. Average yield with and without
7	"	.50	1897	3	103,680	2.38	3.29	2.80	102.5	79 2	6206	Laramie. Sown with Oats in '97, two crops.
8	"	.70	1899	2	100,190	2.30	3.21	2.72	106.1	82.1	1187	Laramie. First year.
9	"	.95	1897	1	42,689	0.98	1.89	1.40	249.0	192.3	3188	Laramie. One-half of plat killed by alkali.
10	"	.03	1895	3	78,219	1.82	2.73	2.24	135.9	104.9	7862	Laramie. Turkestan Alfalfa.
11	"	.98	. . . .	3	103,900	2.38	3.29	2.80	102.3	79.0	. . .	Laramie. With Oats.
12	"	.25	1899	3	104,226	2.39	3.30	2.81	102.0	78.8	. . .	Laramie. First year, with Oats
13	"	.96	. . . .	2	70,132	1.61	2.52	2 03	151.6	117.0	. . .	Laramie. With Oats.
14	"	.46	1899	3	134,165	3.08	3.99	3.50	79.2	61.2	1766	Laramie. First year, with Timothy.
15	"	5.4	1899	2	98,881	2.27	3.18	2.69	107.5	83 0	. . .	Laramie. First year, on sod with Oats.

*Growing season five months, May, June, July, August and September.

ENEMIES OF ALFALFA.

As yet few insect pests of alfalfa have been observed in the state, and no cases of rust or other fungous diseases have come to notice. At Lander one crop of hay was destroyed by the Utah cricket which invaded the farm in great numbers in 1894. At Wheatland one crop was destroyed by caterpillars which the Superintendent reported as army worms. The caterpillar of a small yellow butterfly, closely related to the cabbage worm, has also been reported on the alfalfa at Wheatland, but not numerous enough to do appreciable damage. By far the most serious enemy of alfalfa in this state is dodder. At Sheridan the alfalfa makes strong enough growth so the dodder does not kill it, but the hay is seriously injured by it. The following report on dodder made by the writer in Bulletin No. 16 of this station is here repeated because of its importance and relation to the subject.

"DODDER.—Alfalfa is sometimes affected by rust and insect pests, but as yet its greatest foe in this state is dodder, (*Cuscuta*), there being several species indigenous to this region. Dodder has been quite destructive on the Laramie, Saratoga and Sheridan Experiment Farms. It is a small annual parasitic plant with yellow or reddish-yellow twining stems, which wind themselves around the stems of alfalfa, clover or similar plants, near the ground, taking its nourishment from its host. It has small colorless scale-like leaves and produces clusters of ten or more flowers, each of which contains four small grayish seeds which are about half the size of alfalfa seed. These fall to the ground where they remain until the next season when they germinate. The young dodder plant cannot live long in the ground and unless it finds a host plant, soon dies. Where it is abundant the plants upon which it feeds assume an unhealthy appearance and finally die.

"Dodder can be killed by cutting the hay before the dodder blossoms and burning it, or by plowing the crop under and cultivating the land for a year or two in corn, potatoes or other plants which have stems so large that dodder does not live upon them. Great care should be taken in purchasing alfalfa seed to get that which is pure. If our farmers would raise their own seed it could be kept free from dodder and other weeds and would also have the advantage of being acclimated."

APPENDIX.

OTHER TRIALS OF ALFALFA ON THE LARAMIE PLAINS

In addition to the experiments on the Station farm we give the results which have been obtained by our farmers on the Laramie Plains so far as we could obtain information of trials that have been made. A number of first attempts to grow alfalfa have failed, but these have not been left out on that account. 'Negative results are often as valuable as positive ones. In experimental work the lesson taught by a failure may be as important as that of a success. If the reason for the failure can be pointed out, more may be learned from a knowledge of it than will be learned if the results we strive to obtain are reached without difficulty. In the light of nine years investigation by the Station, we think the results obtained on our farms are encouraging. Heretofore writers on alfalfa have placed its altitude limit at seven thousand feet, but enough has been done by our farmers to demonstrate that it will succeed above that altitude if the conditions of soil and water are favorable. Alfalfa has succeeded so universally at low altitudes in the arid region that there is no necessity of our giving accounts of it there. It succeeds under such wide range of treatment, below six thousand feet above the sea, that there is no longer any question of its value as a fodder plant. We have an account of alfalfa having been planted on the Laramie Plains nearly twenty years ago. Mr. Ryan has told me that about twenty years ago Mr. McCarthy planted a small field of alfalfa on the red land just north of Laramie and that it produced two good crops of hay the second year. It was afterwards neglected and destroyed by stock, drouth, and perhaps the rise of alkali from the land becoming wet through water supplied by an artesian well. We have learned that some plants of alfalfa are still showing on the old Jones and Norton ranch, where it was planted seven or eight years ago and left on the open plains where stock have pastured over it continously. We have already told of the failure with alfalfa by a ranchman who spent large sums in trying to grow it about ten years ago. We have also been told that Mr. J. W. Collins tried it with little or no success. Mr. Oliver Mansfield has tried alfalfa several seasons on his ranch located about twenty miles west of Laramie on the Big Laramie River, but has not obtained a hay crop. It is planted on the river bottom on sandy land, which is located about one-half mile from the river and it is stated that ground water does not come near the surface. However, the plants have turned yellow and been winter killed except on a small spot of clay ground where they have succeeded better. Mr. Mansfield is not satisfied that alfalfa will not succeed and is planning to give it further trial.

Mr. S. A. Crawford sowed one hundred pounds of alfalfa seed two years ago and fifty pounds last year. He secured a good stand but the plants did not make large growth. Stock have been allowed to pasture the young alfalfa. He has confidence it will succeed and will put in an additional amount this spring.

Mr. C. H. Jones has given an account of some alfalfa planted a few years ago on his ranch. It was sown in the pasture where stock have had access to it since, and where no attention has been given to its irrigation and care. The stand was somewhat scattering, but plants have made thrifty growth. Mr. Jones states that he believes alfalfa would be a valuable hay crop for the plains where properly planted and cared for.

Mr. Trabing, who is a pioneer in agricultural investigations on the Laramie Plains, has grown alfalfa for about six years on his farm at Laramie. He states that two good crops have been harvested every year and that much more hay is secured than native grass will produce. He says that the troublesome foxtail all disappears where alfalfa is growing. The alfalfa will freeze out where the ground freezes hard when it is very wet, but where kept dry in the winter no difficulty of the kind has been experienced. Mr. Trabing has demonstrated the success of alfalfa and will plant a larger area to it the coming season.

Mr. M. A. Crout is very enthusiastic over the success of alfalfa on the Pryor ranch, located sixteen miles west of Laramie, under the Pioneer Canal. About six acres of alfalfa were drilled in by Mr. Pryor in the spring of 1898. Mr. Crout, who now occupies the ranch, says he cut the alfalfa twice last season and although it was not irrigated for the second crop a good quantity of hay was obtained. The yield would have been greatly increased if it had been irrigated, but Mr. Crout thinks he makes a conservative estimate when he says that he obtained as much hay as could be produced on four times the amount of land in native grass. He has fed the hay to his cattle during the winter and they have fattened on it. He says further that it is the best hay for all purposes he has ever used. Fed to horses it gave the most satisfactory results and "if a horse is poor and hidebound he can be put into good condition in a short time by feeding alfalfa." The hay was nicely cured and has produced no bloating or other trouble.

The following letter from Mr. Webber shows his faith in alfalfa as a hay crop. He has fed the hay to his milch cows with the best results.

LETTER FROM MR. C. W. WEBBER.

Dear Sir: As there has been quite a difference of opinion in regard to the success of growing alfalfa in Albany County, I will give my experience.

I believe that with proper care to get it started, alfalfa is a successful crop in this part of the state. In 1897 I sowed one acre broadcast after drilling oats for a nurse crop and secured a very good stand. In 1898 I drilled in four acres more, using about 25 pounds of seed to the acre. This seed was planted without a nurse crop. It was watered twice before cutting and turned off about a ton of hay to the acre. The first acre which was sown the year before was cut twice and yielded about three tons in 1899. I drilled about twelve acres more to alfalfa last season. It was drilled as nearly as possible in the same manner as the above four acres. This piece was also watered twice before cutting, with the exception of about two acres which had water once. The land which was only irrigated once was covered with a good stand of plants but the ground became so baked that they did not grow very high. This piece of twelve acres was cut once and yielded about three-fourths of a ton per acre. The four acres drilled the year before was cut twice and yielded three tons to the acre. The first acre that was sown in 1897 winter killed during the hard winter of 1898 and 1899, but clover and alfalfa winter killed all over the East and in Colorado, so the difficulty was not peculiar alone to our conditions of soil or climate. This acre was replowed and alfalfa again drilled in, and it made a vigorous growth last season. The ground was all watered after the last cutting and the alfalfa made a good growth before freezing. I would advise any one contemplating sowing alfalfa to drill it in lightly on a compact seed bed on ground that had been irrigated one or more seasons before, and I have no doubt of their success.

Yours Truly,
C. W. WEBBER.

Mr. Webber's place is about a mile west of Laramie, on the open plains. Some of the land on which he planted alfalfa had been manured and the plants made strong, thrifty growth. Measurements of water made on his place last year showed the amount of water used to irrigate 80 acres to be 153.8 acre feet, or enough to cover the land 1.92 feet deep. We do not know how much of this was used on alfalfa, but it was probably only a proportional amount.

Mr. Thomas Bird, who lives in the Centennial Valley, about thirty-five miles west of Laramie, has written the following interesting account of attempts to grow alfalfa on his ranch:

LETTER FROM THOS. BIRD, CENTENNIAL, WYOMING.

Dear Sir: Some three years ago I sowed alfalfa on about four acres of ground that had been broken two years before. The soil is mostly gravel, but portions are partially clay and all was well tilled. The alfalfa came up the first year and made what appeared to be a good stand. The growth was not large enough to cut the hay the first year. The second year the plants stooled out fairly well and we cut it but did not secure what I would call a good crop, probably one-half ton per acre and only one cutting. The third year, which was last season, nearly all the plants had been killed by excessive cold winter or some other cause, so it will be plowed up the coming spring and other use made of the land. This piece of ground is 300 feet from the river at the farthest point, not more than five feet higher than extreme low water mark and two and one-half feet higher than high water mark. This land has never been irrigated but you will bear in mind that we get more rain at the base of the mountains than falls in Laramie.

In the spring of 1898 we sowed one acre of poor gravelly land not far from above piece to alfalfa. It came up much as did the first sown, but did not get large enough to cut the first year. The second year (last season) we irrigated this piece and cut the hay. We did not get a large crop, but better than we secured the second year from the four acre piece described above. As it stood the winter of one year ago, which was the first after planting the seed, I think that by irrigating it as we should it will probably do something.

Some eleven years ago we sowed about one-fourth acre alfalfa on high ground which is probably six feet above low water mark in the river. This has not been irrigated at any time but there are ten or fifteen stalks which are there still. These have made fine growth and blossomed each season since the second year. Digging around some of these roots I find them at two or three inches from the top of the ground to be from one to one and three-fourths inches in diameter. The rest of the plants died the second or third year after being sown.

This concludes our experience, and while it looks discouraging our opinion is that had we irrigated our alfalfa as it should have been the results would have been different. With proper irrigation I think that at least one good cutting can be made. We think the seed should not be spared in sowing, and when we plant more, as is our intention, 20 or 25 pounds of seed per acre will be used. I have written at some length in order to explain fully what we have done, as you requested. I hope the information may be of value and that it will not deter others from giving alfalfa a fair trial. We are fully convinced of the importance of giving proper attention to the irrigation of alfalfa, at least during the first two seasons of its growth, and with this attention we believe it can be made at least a partial success even at this high altitude.

Yours very truly,
THOS. BIRD.

Mr. Bird's place is in the upper part of the Centennial Valley at an altitude of about 8,000 feet. Undoubtedly much more rain and snow falls in that locality than lower down on the open plains. In my opinion those who have read this bulletin will find a study of Mr. Bird's letter anything but discouraging, as he indicates. The fact that plants have lived for eleven years without irrigation or care at such an altitude certainly shows their hardiness. Alfalfa can not be expected to succeed any place in our state without irrigation. With proper attention it will probably succeed well enough in the Centennial Valley to produce as much or more hay per acre than will native hay.

SUMMARY.

Alfalfa succeeds in all parts of Wyoming under 8,000 feet altitude where it can be irrigated and makes more fodder to the acre than any other hay plant yet introduced.

Under proper care and right treatment, raising alfalfa may be made profitable up to nearly or quite 8,000 feet altitude. It does not require special culture where grown below 6,000 feet altitude.

Between 7,000 and 8,000 feet above the sea, alfalfa can generally be cut twice, though only the first cutting may produce a full crop. Where cut twice in the season the yield is from two and one-half to four tons per acre. Below 5,000 feet altitude it is cut three and four times each season and yields from four to ten tons of cured hay per acre.

At high altitudes alfalfa requires careful treatment to secure a good stand and become well established. Heavy seeding and planting with the press drill are recommended.

Two seasons are required to put the alfalfa into good producing condition on the Laramie Plains.

Alfalfa grows better and produces larger crops for two or three years after planting if sown alone instead of with oats or other nurse crop. This may be due to securing better stand. However, it may be planted with grain and when sown with nurse crop the seeding of grain should be light, and early, small strawed varieties used.

Turkestan alfalfa has stood the winters better and produced heavier crops than the common form at Laramie.

The principal cause of winter killing seems to be the freezing of water around the crowns of the plants.

Alfalfa will not grow on wet land where the ground water stands as near the surface as one or two feet.

No one should expect to obtain good hay crops of alfalfa without regularly irrigating it. It requires occasional irrigations through the growing season, and fall irrigation is beneficial.

The average amount of irrigation water which has been used on alfalfa at Laramie would cover the land 2.22 feet deep. This is a little less than the amount used to irrigate grain and much less than is used on native hay.

Alfalfa grows better where there is some alkali salt in the soil but will not stand more than one per cent of our common white alkali in the first six inches of soil. It should not be planted where there is enough alkali to form white incrustations on the surface of the soil during any part of the year.

The principal enemy of alfalfa in Wyoming is dodder, which may be prevented by using clean seed.

Alfalfa is not only a valuable hay crop but improves the land by taking nitrogen from the air and fixing it in the soil. It is considered the greatest boon tō the west of any plant we cultivate.

(Note.—The next bulletin of the Wyoming Station (No. 44.) will deal with the power of alfalfa to improve the soil for the raising of other crops.)

UNIVERSITY OF WYOMING.

Agricultural College Department.

WYOMING EXPERIMENT STATION,

LARAMIE, WYOMING.

BULLETIN NO. 44.

APRIL, 1900.

ALFALFA AS A FERTILIZER.

BY B. C. BUFFUM.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyo.

Wyoming Agricultural Experiment Station.

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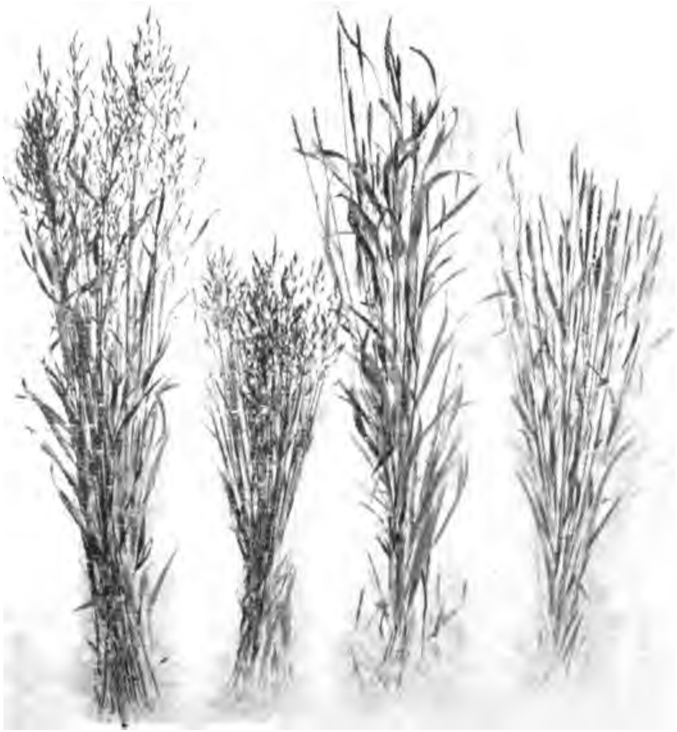

PLATE I.

1.- Oats from Alfalfa land. 2.—Oats from land used for rotation. 3.- Wheat from Alfalfa land. 4. Wheat from land used for rotation.

ALFALFA AS A FERTILIZER AND SOIL IMPROVER.

B. C. BUFFUM.

GENERAL CONSIDERATIONS.

How to make the soil highly productive and keep it so is often one of the most difficult problems the farmer has to solve. The soil is a wonderful compound and studies of it have resulted in some of the greatest discoveries in science. The soil upon which we depend for so many of the blessings we enjoy is not merely a dead, inert mass of particles of rocks which have been torn to pieces by the weather, but is a place of great activity and continual movement, teeming in its dark recesses with forms of life which are so small that we can not see them except with a microscope, but of such importance that the world would neither be clothed nor fed if they did not exist.

The higher plants upon which man and animals are dependent, either directly or indirectly, for food and shelter can only grow in soils which are in favorable condition of tilth and moisture and then only when supplied with the kind of food they require. Out of the fourteen or fifteen different elements which plants must have as food, only two or three can be taken from the air by them, and the rest must be supplied by the soil. If the soil does not contain these elements in sufficient amounts and in such combination or soluble condition that plants can absorb and use them, it will not produce crops. Fortunately nearly all the foods required by plants are so abundant that the farmer needs to give them no attention, and only those which are most rare or which are apt to be present in the soil in such small amounts that they soon become exhausted, become of importance to him. Some soils may be deficient in lime (in regions where there is no lime stone or where the lime is so combined that it is of no value to the soil or plant), but as a general rule the only elements which we need to supply the land are potash, phosphoric acid and nitrogen. Of these potash and phosphoric acid are the most abundant. In the arid regions many of our soils contain so much potash that any amount of cropping will not exhaust it. Our common river sand at Laramie contains over 3.5 percent of potash* so that in one acre of it one foot deep there would be approximately 150,000 pounds of potash, more than enough to supply large crops of wheat for a thousand years.

The fine earth on the Laramie farm, after the sand and gravel had been sifted out, contained 0.56 percent of potash**, fully enough to last our wheat crops two hundred years if we do not call on the supply from deeper soil or the coarser particles, which are largely pieces of granite rich in potash. This estimate is only a rough one, but it serves to show the abundance of such foods in our soils.

Phosphoric acid is not so abundant, but our soils contain a sufficient amount as a rule. It is true that these elements are often abundant in the soil and still not available to plants, as they are in combination and insoluble. This is more apt to be the case if the soil is not in good tilth. Since the time of Jethro Tull, nearly 200 years ago, the importance of tillage has been known, though not fully appreciated by many. Tull thought tillage the only thing necessary to make and keep the land productive. This is

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*Analysis made by A. H. Danielson, B. S., March, 1900.

**For analyses of Wyoming soils, see Bulletin No. 6, Wyoming Experiment Station, by Prof. E. E. Slosson. Pages 13 to 26, probably true in the arid region so far as potash is concerned, but tillage does not add new food to the soil except as it favors the multiplication and work of the organisms in the soil which appropriate nitrogen from the air and change that obtained in other ways into forms made use of by plants. Nitrogen is one of the most common elements, as it composes about four-fifths of the air, but as a plant food it is not abundant and is the most expensive fertilizer the farmer has to provide, at least where purchased in commercial form. Plants* can make use of nitrogen only when it is in the form of nitric acid or perhaps ammonia.

The larger part of the nitrogen in the soil is the result of decaying vegetable matter which produces humus. Because of the small amount of vegetation on our arid soils they are usually poor in humus and nitrogen. If they are in good tilth and yet become unproductive it is generally because the nitrogen has become exhausted. It may be added to the soil by applying commercial fertilizers which contain it, as nitrates, raw bone meal or other organic compound or with barnyard manure which contains large amounts of vegetable matter, ammonia and other forms of nitrogen. Among all fertilizers, the first of importance is nitrogen, and the fertilizer which contains the most of it in the form needed by plants is the most valuable. Sir William Crooks, one of the world's foremost scientists, has predicted that wide-spread famine will finally result from the failure of the wheat crops of the world because the nitrogen of the soil is being exhausted and there is such general waste of this element instead of returning it to the land.

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*Plants as here spoken of refers only to the higher plants, those which produce flowers and seeds. The minute organisms in the soil known as bacteria or ferments, which change other forms of nitrogen into nitric acid, are also classed as plants, but in popular usage the word plants does not include them.

RELATION OF ALFALFA TO THE NITROGEN PROBLEM

There is another way of supplying the soil with nitrogen, viz.: by growing plants which have the power to take up free atmospheric nitrogen and fix it in the soil. One of the most remarkable discoveries in science was the fact that certain plants can do this and the way in which the nitrogen from the air becomes fixed through the agency of certain minute organisms (bacteria) which take nitrogen gas from the air that passes into the soil and so change it that it becomes food for plants. These bacteria work in connection with plants* belonging to the pea family, pease, beans, clover and other legumes, by producing little bunches or nodules on the roots in which they live.

There is a different organism for each kind of plant. They are spread through the soil and take up their abode on the roots of the plant to which they are related when it is grown, and the plants do not grow well if the organisms are absent.**

Alfalfa is hardy enough to stand our climate, easy to grow, gives as large or larger money returns from the land as will grain*** and improves the soil at the same time at no expense to the farmer.

The fixation of nitrogen by alfalfa overcomes the principal difficulty with arid soils and a rotation of crops in which alfalfa is one, practically solves the fertilizer problem over a large part of the west.

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*These bacteria are low forms of plants. When different plants live together for the mutual benefit of both, it is technically known as "symbiosis." There are many instances of symbiosis in the plant world.

**The minute organisms which work with alfalfa seem to be abundant in our soils. If they were absent the plants would not do so well, if they did not entirely refuse to grow. If alfalfa does not thrive, inoculating the soil with them might remedy the difficulty. Such inoculation has been put into practice with clover and the Germans have put the bacteria on the market for this purpose under the name of "Nitragin." It is necessary to get the right kind of bacteria, however, and I do not know that the one for alfalfa has ever been sold.

***For information in regard to alfalfa as a hay crop in Wyoming, see Wyoming Station Bulletin No. 43.

ALFALFA IMPROVES THE PHYSICAL CONDITION OF SOILS

Besides fixing nitrogen in the soil alfalfa improves its tilth or physical condition. The plants shade the land, prevent the rapid loss of water by evaporation and the rise of alkali salts to the surface. The roots have an important mechanical effect also. They grow to large size and penetrate to unusual depths in the subsoil. When the land is plowed to destroy the alfalfa, the roots decay, producing humus which aids in loosening the soil, holds moisture and helps other plants make use of the nitrogen which has accumulated. It is not necessary to plow under a crop of growing plants to secure the improvement though green manuring in this way is often practiced with good results. At Wheatland the superintendent of the sub-station farm, Mr. M. R. Johnston, practiced plowing under the last crop in the fall. The first and second crops were cut for hay which he states paid for the expense of planting and use of the land and made the fertilizer cheaper than any other which could be applied.

Alfalfa also solves the weed problem. Where land has become infested with weeds, growing alfalfa two or more years will entirely clean them out of the land. Even foxtail*, which is so troublesome in parts of Wyoming, succumbs to alfalfa treatment. We can not expect to destroy foxtail everywhere this way, as it grows in places not suitable for alfalfa, but where alfalfa will grow and is cut two or more times in a season, foxtail or any other weed which may be present soon disappears.

ROTATIONS WITH ALFALFA.

Where alfalfa is used in rotation with other crops, the texture and richness of the soil is improved and the land is kept highly productive, providing of course it is not poor in plant foods which are usually abundant. A good rotation for the Laramie plains would be, beginning with the virgin sod; first year oats, second year potatoes with fertilizer, (stable manure) if possible; third year alfalfa sown on the potato ground without replowing, having it smoothed and leveled. The alfalfa may be left on the land any number of years. Then, beginning with alfalfa, which is to be plowed for other crops, would recommend, first year wheat, oats, barley or potatoes. If crops are good it may be put in grain two or more years. The first year there may be alfalfa growing with the grain, as the plow may not cut off all the roots, but it will do no harm, as the grain roots are small and feed in the surface soil while the alfalfa feeds from below. Follow the grain with potatoes or other cultivated crop and then alternate grain and potatoes for a few years or until the land shows signs of running out, when it should be again put into alfalfa. If land is scarce it may be sown with a light seeding of oats as a nurse crop but for our high altitudes we have found it better to plant the alfalfa alone.

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*The grass popularly called "foxtail" in the west is not the common foxtail of the East, which is a valuable grass. The grass under this name with us is a wild barley (Hordeum jubatum), sometimes known as Squirrel Tail Grass. For an account of it as a stock pest in Wyoming, see Wyoming Station Bulletin No. 19, by Prof. Aven Nelson.

ALFALFA AS A FERTILIZER ON THE LARAMIE PLAINS

We have carried out an experiment at the station farm to show the value of alfalfa as a fertilizer.* While only one year's crop has been raised since plowing up the alfalfa, the results are well worth considering. In order that an understanding of the full effect of having grown the alfalfa on the land for a number of years may be had, we give a full historical report of the acre plat on one half of which alfalfa was grown and plowed under for the pro-

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*It is a pleasure to acknowledge the efficient help Mr. W. H. Fairfield has rendered in the work of the department. He carefully managed this experiment, and his field notes and records make the results accurate and valuable. Mr. A. H. Danielson has also given efficient aid.

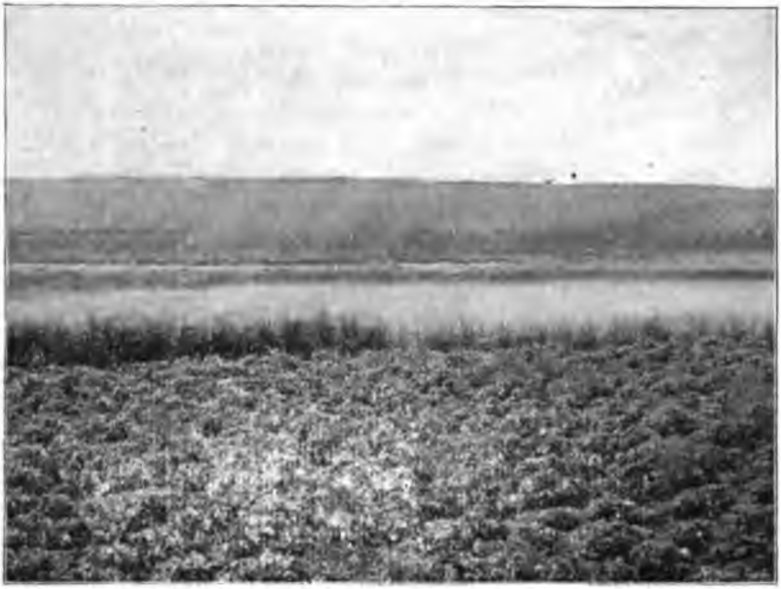

Fig. 1.

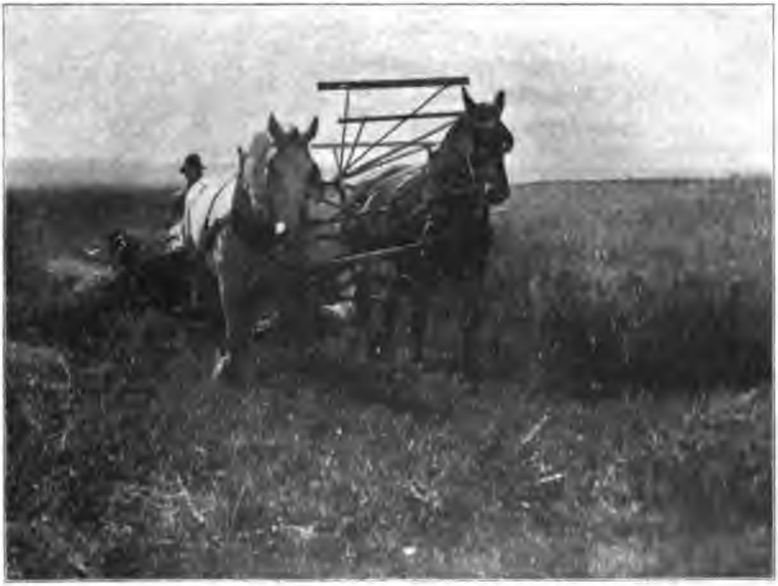

Fig. 2.

PLATE II.—Fig. 1 Oats and Potatoes on Alfalfa and other ground. Left side of picture where Oats are heavy is Alfalfa ground. Fig. 2. Cutting Oats on Alfalfa ground.

duction of other crops and on the other half has been grown crops other than alfalfa in rotation for the same length of time.

HISTORY OF ACRE PLAT 8.

1891.—In May the virgin soil was broken to a depth of five inches, and was planted on June 3 to strips of Indian Millet, German Millet, Jerusalem Corn, Kaffir Corn, Hemp, Sorghum, Sunflowers, Castor Beans and Corn. These crops did not mature and no record is at hand to show that they were harvested.

1892.—The whole plat was plowed to a depth of eight inches in May or latter part of April, divided into fourths and planted June 2d to pease and beans with press drill and the land rolled after planting. Scotchman Pease and Boston Small Pea Beans were frosted before ripe and not harvested. Canadian Field and White Canada Pease ripened partial crops. They were harvested September 1 to 5 and yielded 5 to 7 bushels pease per acre. They were frosted August 29th.

1893.—On April 17th the whole plat was plowed ten inches deep, harrowed twice April 21 and rolled. May 1 the north half of the plat was sown with alfalfa, broadcast, at the rate of 20 pounds seed per acre. The south half of plat was planted to two kinds of rutabagas.

NORTH HALF.	SOUTH HALF.
Alfalfa.—A good stand was not secured. Was not harvested this year.	**Rutabagas were all destroyed by flea beetles, so no crop was produced.**

1894.—In winter of 1893-4 twelve loads stable manure were distributed as nearly even as possible over the plat. The whole acre was again plowed eight inches deep and harrowed twice.

NORTH HALF.

April 27, resown with alfalfa at rate of 39 pounds of seed per acre. Good stand and made excellent growth. A few bunches of previous years planting which were not cut off by plow growing. Harvested Aug. 16. Yield, 1967 lbs. cured hay per acre.

SOUTH HALF.

Two rows of broom corn 30 inches apart planted along one side. Season too short for it to mature. The remainder of the half acre was planted to varieties of potatoes on May 9, at rate of 1,000 pounds seed per acre. Harvested Oct. 1 to 4. Average yield of 50 varieties per acre, 9,900 pounds marketable potatoes. Average percent of tubers large enough for market, 87, or total yield including small potatoes, 11,300 pounds per acre.

1895.—

NORTH HALF.

Alfalfa was cut twice.

First crop harvested Aug. 6. Yield, 5,019 pounds per acre.

Second crop harvested Sept. 24. Yield, 2,557 pounds per acre.

Total yield for season, 7,576 pounds cured hay per acre.

SOUTH HALF.

Plowed eight inches deep on April 8. Sown to varieties of wheat, barley and oats in rows 15 inches apart with the exception of New Black barley, a small strip of which was sown with press drill eight inches apart. There was about the same area each of oats and barley, which occupied about one-fourth acre, and the wheat covered one-fourth acre.

Average yield per acre of seven varieties of barley, straw and grain, 3,536 pounds. Grain, 1,371 pounds.

Average yield per acre of six varieties of oats, straw and grain, 4,024 pounds. Grain, 970 pounds.

Average yield per acre of 15 varieties of wheat, straw and grain, 6,026 pounds. Grain, 1,768 pounds.

1896.—

NORTH HALF.

Alfalfa was cut twice.

First crop harvested July 7. Yield cured hay per acre, 1,641 pounds.

Second crop was harvested September 8. Yield cured hay per acre, 3,040 pounds.

Total yield per acre for season, 4,681 pounds.

Hail storm injured the first crop, which accounts for small yield.

SOUTH HALF.

April 22-23, plowed eight inches deep. Harrowed, leveled and sown with press drill to varieties of barley at the rate of 100 pounds seed per acre, in strips running east and west. Straw produced was short and yield small.

Average yield per acre of nine varieties of barley, grain, 895.5 pounds.

September 3, land was plowed about eight inches deep.

1897.—

NORTH HALF.

Alfalfa was cut twice.

First crop was harvested July 16. Yield of cured hay per acre, 3,860 pounds.

Second crop was harvested September 9. Yield of cured hay per acre, 3,860 pounds.

Total yield for season per acre, 7,720 pounds.

SOUTH HALF.

April 20, leveled and drilled with Lincoln oats at different rates of seed per acre, from 40 to 120 pounds.

Average yield of grain and straw per acre, 2,617 pounds. Grain, 1,076 pounds.

1898.—

NORTH HALF.

Alfalfa was cut twice.

First crop was harvested July 17. Yield per acre of cured hay, 4,759 pounds.

Second crop was harvested September 8. Yield per acre of cured hay, 3,909 pounds.

Total yield for the season, per acre, 8,668 pounds.

SOUTH HALF.

April 16-19, plowed eight inches deep and leveled. April 29, planted to spring rye at the rate of 114 pounds of seed per acre. Harvested August 13.

Yield per acre, straw and grain, 1,580 pounds. Grain, 556 pounds.

On September 22 and 23 the whole plat was plowed to a depth of about 8 inches. It was not very well done on the north side, as the plow used was not suited to the purpose and all the alfalfa roots were not cut off.

Since cropping was begun on the two parts of the plat separately in 1894 the following crops have been produced on each half of the plat. The yields here are for each half acre instead of yields per acre as reported above:

NORTH HALF—ALFALFA.
One-half Acre.

	Pounds.
1894	984
1895	3788
1896	2341
1897	3860
1898	4334
Total	15,307

SOUTH HALF—OTHER CROPS
One-half Acre.

	Pounds.
1894—Potatoes	5650
1895—Grain and straw	2264
Of which amount the grain is	685
1896—Grain and straw	[*]1280
Grain alone	448
1897—Grain and straw	1309
Grain alone	538
1898—Grain and straw	790
Grain alone	278
Total potatoes	5650
Total straw and grain	5643
Total grain	1949

[*] Estimating that grain is 0.35 percent of grain and straw together.

A rough estimate of the value of the crop from each half acre for the above five years at local prices would be approximately for north half, alfalfa, $60[*] Potatoes and grain from the south half, $69. The total expense of harvesting the alfalfa should not exceed $10.00, estimating from what the actual cost per ton would be on large areas. The south half should have expense of preparing the land for crop each season deducted as well as value of seed, harvesting and sacking the potatoes and threshing the grain.

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[*] This estimate is conservative, as it is based on a value of $8.00 per ton in the local market. The scarcity of alfalfa hay makes it of greater value than native hay, and the price of native hay has rarely been lower than $8.00 per ton, while a part of the time it has brought twice this amount. All the alfalfa could undoubtedly have been sold for $10 to $15 per ton, and certainly would have brought enough more than $8.00 to pay all expense of marketing it.

A rough estimate of this expense on the south half of the plat would place it at about $25. This would make the net value of the alfalfa from one-half acre $50, and of grain and potatoes from one-half acre for the same time $44. Comparing the crops produced each year, the production increased from the alfalfa land, while it decreased to such an extent from the plowed ground that the last crop of rye gave barely ten bushels of grain per acre, though last season it produced much better yields of wheat and oats.

This brings the history of acre plat eight down to the spring of 1899 and the following report shows the value of having grown alfalfa on the land for other crops. The alfalfa stubble was plowed under in the fall after the second hay crop of 1898 had been removed.

YIELDS OF WHEAT, OATS AND POTATOES ON ALFALFA LAND.

April 25, 1899, acre plat 8, all of which had been plowed the previous fall, was harrowed twice and leveled or planked twice. The east one-third of the plat was planted to wheat by drilling north and south, so one-half would be on the alfalfa land and the other half on that part of the plat which had been growing other crops. In like manner oats and potatoes were planted on the other two-thirds of the plat. In planting the potatoes the west third of the plat was again plowed, dropping the seed in every third furrow. The comparative lengths of straw and heads of the oats and barley are well shown in our illustration made from a photograph of as nearly average plants as could be selected from each portion of the plat. The appearance of the oats at each end of the plat is shown in the illustration used as frontispiece. The divisions were not made equal, and the area of each crop varied somewhat, so the results are all reported on the acre basis. What the lasting effect is on the soil will only be known after other seasons' crops have been studied.

WHEAT—The increase in yield on alfalfa land is shown in Table 1. Over 60 percent larger yield was obtained on the north side of the plat where alfalfa had been grown before, and the grain weighed more per bushel. However, the conditions of growth being so much better, it took longer to mature and the grain was not fully ripe when it was lightly frosted on August 24. There was a smaller number of smutted heads also in the grain on the alfalfa end of the field. At local market prices an increase of seven to twelve dollars' worth of wheat per acre was the result of using alfalfa ground on which to plant it. As shown above, fertilizing the land with alfalfa cost nothing, as the value of the hay produced was equal to other crops on the other part of the land.

TABLE I.—*Wheat. Scotch of Scotch. Laramie, 1899.*

PART OF PLAT	Area	Date Planted	Date Ripe	Height of Grain	Length of Heads	Per cent of Smut	Yield per acre Straw and Grain	Yield per acre Grain	Weight per bushel
	acres			*ft.*	*ft.*		*lbs.*	*lbs.*	*lbs.*
South (rotation)...	0.14	April 27	Sept. 7	3.00	0.25	17.6	2895	1085	56
North (alfalfa land)	0.17	April 27	Sept. 14	3.75	0.30	16.8	5118	1803	58
Gain on alfalfa land	....	....	....	.75	0.05	0.8	2223	718	2

OATS.—(Table 2.) The yield of grain was about 48 percent greater on the alfalfa land than on the land which had been growing potatoes and grain. Nearly 78 bushels per acre was produced on the north (alfalfa) end of the plat and 37 bushels per acre on the other land, using the weight of 32 pounds per bushel for the computation. The grain stood nearly one and one-half feet higher and the heads averaged nearly two inches longer, but the grain took much longer to ripen on the alfalfa land. Unfortunately the comparative weight of the oats for the two kinds of land can not be given, as one of the records was lost. They weighed 43 pounds per bushel from the alfalfa ground. Plowing under alfalfa stubble increased the value of the crops about $16 per acre at the market price in Laramie, and the fertilizing was done without expense.

TABLE II.—*Oats. Highbred. Laramie, 1899.*

PART OF PLAT	Area	Date Planted	Date Ripe	Height of Grain	Length of Heads	Yield per acre Straw and Grain	Yield per acre Grain	Weight per bushel
	acres			*ft.*	*ft.*	*lbs.*	*lbs.*	*lbs.*
South (rotation). . . .	.14	April 27	Aug. 26	2.8	0.50	2744	1193	. . .
North (alfalfa land). . . .	.16	April 27	Sept. 6	4.2	0.65	7529	2484	43
Gain on alfalfa land . .	. . . .	. . . .	. . . .	1.4	0.15	4785	1291	. . .

POTATOES.—The potato crop of last season was a failure. It was the first season since 1893 that potatoes have not produced good yields on the Experiment Farm. The reason seems traceable to the unusually short season with cold nights and generally poor growing weather. However, our results to show the effect of plowing under alfalfa for potatoes are comparable and show the effect on the crop as well as would be the case if the yields were large. The yield of marketable potatoes was increased over 62 percent on the alfalfa land and the potatoes averaged larger in size. The increased cash value of the crop was about $16 per acre at local market prices, at no cost for the improvement in the soil which caused the increase.

TABLE III.—*Potatoes. Early Ohio. Laramie, 1899.*

PART OF PLAT	Area	Date Planted	Date Harvested	Yield per acre Marketable	Yield per acre Small	Total Yield per acre	Per cent Marketable
	acres			*lbs.*		*lbs.*	
South (rotation). . .	0.13	May 18,19	Sept. 30 Oct 7	2616	528	3144	83.2
North (alfalfa land). .	0.16	"	"	4219	663	4882	86.4
Gain on alfalfa land .	. . . .	. . . .	. . . . . .	1603	135	1738	3.2

SUMMARY.

The most important fertilizer for the arid region is nitrogen.

Some plants, of which alfalfa is one, have the power to fix in the soil free nitrogen of the air. They do this by means of micro-organisms which form bunches or nodules on the roots.

Therefore growing alfalfa on the land increases the amount of nitrogen in the soil and practically solves the fertilizer problem for the west.

Alfalfa also improves the soil tilth by shading the ground and adding humus to the soil by the decay of its large, deep-growing roots.

Growing alfalfa destroys weeds.

The value of alfalfa harvested from one-half acre of land for five years at Laramie was about $50 more than the cost of producing it.

The value of potatoes and grain from an adjoining half acre for five years was about $44 more than the cost of producing at local prices.

When the alfalfa land was plowed and planted to wheat it produced $8 to $12 more value in wheat per acre than the land which had grown potatoes and grain before.

When alfalfa land was plowed and planted to oats it produced $16 worth of grain more than land which had grown potatoes and grain before.

When alfalfa land was plowed and planted to potatoes it gave $16 worth more of potatoes per acre than was obtained from land which had grown potatoes and grain before.

By growing alfalfa, the above increase of yields and values were produced with absolutely no cost for fertilizing the land.

UNIVERSITY OF WYOMING.

Agricultural College Department.

WYOMING EXPERIMENT STATION,

LARAMIE, WYOMING.

BULLETIN NO. 45.

JUNE, 1900.

A PRELIMINARY REPORT

. . . ON THE . . .

ARTESIAN BASINS OF WYOMING.

WILBUR C. KNIGHT.

Bulletins will be sent free upon request. Address: Director Experiment Station, Laramie, Wyo.

Wyoming Agricultural Experiment Station.

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A PRELIMINARY REPORT

. . . ON THE . . .

ARTESIAN BASINS OF WYOMING.

W. C. KNIGHT.

Introduction.

The object of this bulletin is to place before the citizens of Wyoming a preliminary treatise on the artesian basins of this state and show how this information is available for the agriculturist, stockmen and communities in general. In order to do this it has been found necessary to introduce in a very brief manner a resume of Wyoming geology. This is of necessity technical, since there are no common names to be substituted for scientific ones. I realize fully how difficult it is to popularize a subject of this kind and at the same time make it comprehensive without writing page upon page of explanation that would increase the bulletin beyond a reasonable limit. If I can present the scientific information in such a manner that the citizens of this state can understand the essential features of our artesian basins and be able to locate artesian wells, I will feel that I have fully accomplished my purpose.

Without a scientific treatise relating to the artesian basins there would be no means of discussing the basins, locating them, or referring to the water-bearing zones. Scientific terms in connection with the geology will, as a rule, be defined, so that those who are unfamiliar with the history of our earth can read intelligently. To aid the explanations many illustrations are used and an accompanying map will aid materially in showing the distribution of the many formations.

The question of securing good artesian water in any part of Wyoming is a very important one. Already, nearly all of the available water from our streams has been appropriated, and the springs and tiny brooks are being fenced up, so that in a few more years not many natural watering places will remain open for stock of any kind. Unless wells are drilled large tracts of land in our state, such as the Red desert, the desert north of the Rattlesnake mountains and country north of Casper will remain as they are today—winter sheep ranges—winter ranges because the flockmaster depends on snow to water his herd. If wells are to be drilled the artesian well is the most desirable. Unless the supply of water can be greatly increased large tracts of valuable land must remain as grazing land only—of little value to the owner since it produces so little, and an obstacle to the state because it cannot be taxed for hay or agricultural land in place of grazing. The Powder River country, which is as a rule low and fertile land, has not sufficient water to irrigate 10 per cent of the vast area. On the south side of the Ferris and Seminoe mountains agriculture is an impossibility under existing conditions, since there are no streams of any consequence along these ranges. North of the Shirley mountains conditions are similar, as they are in numerous other places in the state. Imagine what would happen if all of the country east of the Laramie mountains could be irrigated.

How far artesian wells will solve any of these problems remains for experiment to prove; but without question they will be found beneficial in many instances, and when a system of deep well drilling has been inaugurated the water supply will be sufficient to carry on irrigation on a large scale. One has to go only to Dakota to realize the possibilities of irrigation by means of artesian water. Artesian basins are numerous in Wyoming and some of them are very large and especially well located. So far but little attention has been given to this subject. A few shallow wells have been drilled in several counties, but none of them have gone to a sufficient depth to secure a large flow. Few, if any, have thus far contemplated sinking deep wells with a view of obtaining more than a slight flow. To those who wish to increase their present water supply I refer to the artesian wells of Dakota, where in a few instances water has poured forth under a pressure of 150 pounds per square inch and has been used as a water power as well as to irrigate with. The Dakota artesian basin depends largely upon the Black Hills for its water supply; possibly this may be augmented by the waters from the Big Horn mountains, but this is not probable. Judging from the source of the water in many of the Wyoming basins, the artesian wells in this state should equal any that have been drilled in South Dakota. The high mountains, clothed with pine and spruce forests, and the peaks of perpetual snow, furnish day by day a constant water supply which sinks down between the strata and may be tapped with a drill a thousand or more feet lower than the source.

The data employed in this bulletin have been collected by me during the last four summers. Occasional references are made to some of the early reconnaisance surveys; but all of the structural features have been workd out from field notes. The geological map embodies all that is known of the geology of Wyoming up to date. All of the early maps have been examined and their data used so far as it harmonizes with recent investigations. This map can only be considered reconnaisance work; hence an allowance will have to be made for variations in boundaries between eras and in a few places for structure. For example, the country east of Laramie peak and at the head of the Wind river are not well known and more than likely the geology of all of Uinta county north of the Oregon Short Line railroad needs careful revision. There are numerous small areas all along the east side of the Laramie mountains that have not been examined. There are in fact numerous places all over the state where greater detail can only be worked out by careful examination. The map has been constructed to illustrate the distribution of the various formations in the state and to act as a key to structural geology. For these purposes it will be found very reliable, and those interested in securing artesian wells will find it a valuable aid. No attempt has been made to show the topographical features, since only a very small portion of the state has been surveyed. Accompanying the bulletin there are nmerous geological sections which will be found to be indispensable in considering the structure of the various artesian basins.

Judging from what has been done in the past, it will be many years before the citizens of this state will attempt to increase the water supply by means of artesian wells and it may be possible that the state may have to lend aid to this very commendable enterprise. It will be well for our next legislature to consider the advisability of drilling test wells in the artesian basins where water is most needed, and in this way encourage ranchmen to drill for themselves. In case test wells are put down by the state, the location should be carefully selected and only deep wells drilled. Otherwise many would be discouraged on account of slight flows.

I take this opportunity to thank the United States Geological Survey for electrotypes of the Fort Benton and Niobrara fossils, used in this bulletin; also to thank Prof. Charles Fulton for assisting me in drawing the map and sections, and Mr. Frank Bond for producing such excellent drawings of fossils, which add so much to the bulletin.

A Geological Sketch.

In the following pages will be found a very brief description of the geological formations known in Wyoming. An attempt has been made to describe the various formations so that people residing in any part of the state can work out for themselves the geology of their region and conclude whether or not they wish to attempt drilling for artesian water. Prior to describing the formations I have introduced a scheme showing the names and subdivisions of geological time as applied to Wyoming geology. The top of the scale represents the latest formation and the bottom the oldest.

CENOZOIC	Pleistocene	Recent.	
		Champlain.	
		Glacial.	
	Tertiary.	Pliocene ?	
		Miocene.	
		Oligocene.	
		Eocene	Bridger.
			Green River.
			Wasatch.
MESOZOIC	Cretaceous	Laramie	Fort Union?
			Lower Laramie.
		Montana.	Fox Hill.
			Fort Pierre.
		Colorado	Niobrara.
			Fort Benton.
		Bear River.	
		Dakota.	
	Jurassic	Como.	
		Shirley.	
	Triassic.		
PALEOZOIC.	Permian.		
	Carboniferous	Upper.	
		Lower.	
	Devonian.		
	Silurian (absent)		
	Ordovician.		
	Cambrian	Upper.	
		Middle.	
PROTEROZOIC. (EOZOIC)	Algonkian	Not subdivided.	
AZOIC	Archæan	No natural subdivisions.	

Before taking up the geological discussion it must be understood that nearly all of the stratified rocks have been deposited in seas or fresh water lakes. The name stratified rocks includes limestones, sandstones, shales, slates, conglomerates, as well as most of the clays and marls. During the geological history of our earth all, or nearly all, of the land has been covered with water, and usually many times. If there were no seas or lakes, no rocks were deposited, and the formation is absent. One can form a better idea of geological time if he will consider that there have been constant changes in both sea bottom and land surfaces. The period in which a sea bottom was gradually settling means that there was deposited a very thick band of rocks. If the sea was deep and water clear, limestones were made. If clear, limestones were also made in shallow water. Along coast lines, where sand was produced, sandstones were formed, together with other strata as conglomerates and breccias. In gulfs and bays where there were large rivers emptying, fine sediment and mud accumulated, which were later compressed into shale. If a formation is present in Wyoming, it means that a sea or lake existed during that period; if absent, it means that the state, or that part of the state in which the strata are absent, was dry land. In the same way we can judge of the duration of a geological period by considering the thickness of the rocks deposited. For example, the Paleozoic rocks in Wyoming are not to exceed 3,000 or 4,000 feet thick, while in Pennsylvania they are over ten times that thickness. From this we gather that Wyoming was dry land for the greater part of the Paleozoic era.

Azoic Era.

This represents geological time prior to the appearance of life on earth. The rocks are chiefly granite, and none of the metamorphosed sediments are included.

THE ARCHAEAN PERIOD.

The name Archæan applies to the oldest rocks that we know anything about on our earth. Usually they are granite, gneisses and schists, with granite predominating. Originally the Archæan not only included the above rocks, but also very thick bands of metamorphosed sediment, which have recently been separated from the Archæan by the United States Geological Survey and called the Algonkian. In accordance with the Canadian geologists, the Archean is divided into the Laurentian and Huronian, the Huronian being largely metamorphosed sediment. Under the more recent classification the Huronian belongs with other formations to the Algonkian. The name Archæan restricted as given above, has in it no evidence of life or anything pertaining to life. The rocks were in all probability of eruptive origin and represent the so-called crust of our earth prior to the deposition of any sediment. Other views are held as to the origin of these rocks; but the question of origin cannot be discussed here. The Archæan, then, is the fundamental or primary formation that formed at one time the entire sea bottom and the entire land masses—a formation universal. All of the sedimentary depositions have tended to bury these oldest rocks and in consequence there are only occasional areas exposed, and the most of these in Wyoming occur along the crests of the mountain ranges; when huge folds elevated them while they were covered with many thousand feet of sedimentary rock. The sedimentary rocks have since been removed by erosion. In the Sweetwater valley there are numerous peaks of granite that appear to have been constantly above the sea since the beginning of the Archæan era. There was in all probability a large Archæan land mass in this region that remained above the sea from Archaean time up to nearly the close of the Tertiary, when it was depressed and covered with a few hundred feet of Tertiary strata. Typical Archæan exposures can be seen at Sherman, Laramie peak, east of Whalen canon, along the Big Horn, Wind River, Gros Ventre, Medicine Bow, Ferris, Seminoe and Owl Creek ranges, along the Sweetwater river, a few miles northwest of Rawlins, and north of Clark's Fork, in Big Horn county. These rocks are usually mineral-bearing and when cut with dikes of porphyry make the conditions ideal for the occurrence of all of the precious metals.

The only way that this, the oldest of formations, can affect the artesian basin, is that it forms the highest mountain ranges, where vast quantities of snow accumulate during the winter to feed the basin with water during the summer months, and also forms a bed rock in many localities on which rests the lowest and the greatest water zones in the state. The term bed-rock as used in connection with this bulletin, means the Archæan granite. Springs are quite numerous in this formation, but since the rocks are not stratified there are no water-bearing zones that can be traced. Wells of the very best water can be found in the granite rocks and occasionally the water will rise to the surface and flow in a small stream. Usually wells put down in these rocks have to be provided with some means to elevate the water.

Proterozoic Era.

(EOZOIC.)

This marks the first era of sedimentation; also the introduction of life on earth. The rocks are usually sedimentaries that have undergone extensive metamorphism, and are schists, marbles and quartzites, together with intrusive bands of eruptive rock. They are also acutely folded and nearly all of the evidence of fossil remains has been obliterated. The Proterozoic also marks the first great mountain-making period of our earth. These rocks are found unconformable with the Archæan.

ALGONKIAN.

Up to the present time the Algonkian rocks of Wyoming have been referred to the pre-Cambrian and have not been separated from the Archæan. They form important bands in numerous localities and have in this bulletin, so far as the data have warranted, been separated from the Archæan. The formation is composed of schists in great profusion, marbles, quartzites and these cut with dikes of eruptive rocks. The strike of the entire formation varies from north to northeast, and the dip of the strata is seldom less than 65 or 75 degrees. It is unconformable with the Archæan and is found in great granite basins. The thickness of the entire series has not been absolutely measured, but including the eruptive band, which does not form an important part, the maximum thickness in Wyoming is about 20,000 feet. Typical areas have been found in the Black Hills in Wyoming, and occasional outcrops to the southwest from that place to the Hartville hills—one exposure being east of Lusk, another at Rawhide Butte, and a large one in Whalen canon. They also occur at Halleck canon, Plumbago canon, in the Medicine Bow mountains, nearly all of the Sierra Madre mountains, in the Seminoe mountains and in the Sweetwater mining district of the Wind River range. None of these localities have been examined in detail; but sufficient work has been done to prove that these rocks were at one time sedimentary and that they have been changed by metamorphism to schists. In the Sweetwater districts the rocks are chiefly schists; but there are many bands of eruptive rock that form dikes which follow the strike of the formation

We have every reason for believing that life was born on earth during the Algonkian period; in fact a few fossils have been reported from rocks supposed to belong to this formation. At the close of this period in Wyoming there is evidence that great mountain ranges were formed. A very prominent one extended from the Laramie mountains north and east to the Black Hills, the remnants of which are still visible. A second prominent range extended from South Pass northeast to an unknown distance. After the mountains were formed they remained dry land a sufficient length of time to have these ranges reduced to mere hills, and in many places to almost plains, and upon their upturned edges was deposited the Cambrian strata.* On account of the strata being highly inclined and ther being no basins in which water could accumulate under much head, none of this series can be seriously considered as valuable artesian basins. However, a small flow of artesian water may be found in several of these areas.

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*In Michigan, the Algonkian rocks contain very extensive deposits of both iron and copper and usually they are mineralized wherever found. In Wyoming mines of gold, copper, silver, lead and iron occur, in the camps at South Pass, Encampment, Seminoe and the Black Hills.

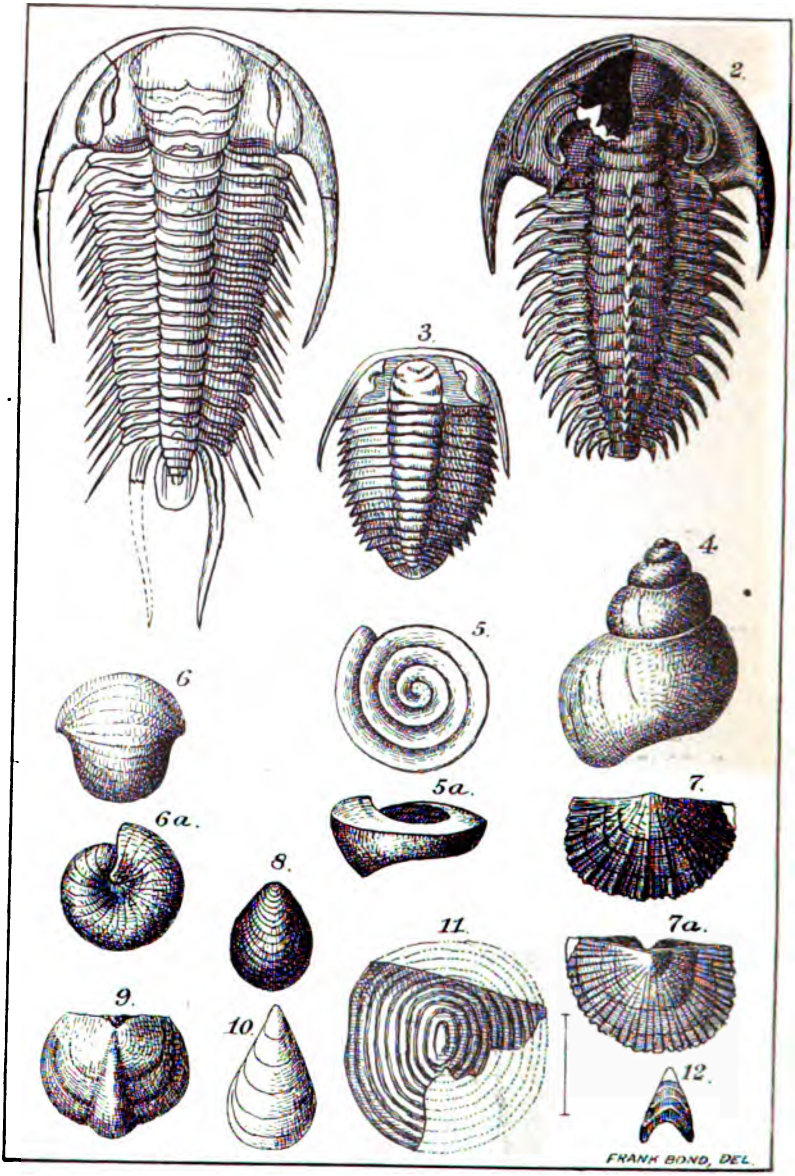
The Paleozoic Era.

The Paleozoic rocks in Wyoming rest unconformably upon the Archean and Algonkian, and vary in thickness from 1,000 to 4,000 feet. Along the Appalachian mountains rocks of the same era have a thickness of 40,000 or 50,000 feet. In Wyoming the Paleozoic rocks are nearly all limestones, with a few bands of calcareous sandstone, some sandstone, quartzites and conglomerates. These occur along the mountain sides, dipping at various angles and sometimes reaching elevations of 9,000 or 10,000 feet. Along the western flank of the Big Horn and the eastern flank of the Wind River range these rocks extend from the granite to the base and practically cover the mountain slopes. Upon reaching the foot of the ranges the Paleozoic rocks dip beneath later formations. From a life standpoint the Paleozoic era was the first important period in the world's history. Life had existed for some time prior to the advent of this era; but it was represented so far as we know only by a few inferior sea animals and the impressions of these have been largely obliterated through the metamorphism of the strata. Conditions changed at the commencement of the Paleozoic and for the first time in the world's history the seas were teeming with invertebrate life. Associated with these were numerous kinds of sea weeds. The life was very simple to start with, but as geological time went on it became more and more complicated. The sea life changed from invertebrates to vertebrates (fishes). Some of the invertebrates of the sea developed into land animals (insects), so that from the beginning to the close the era is one of great biological progress. From the fishes, amphibians developed, and from the amphibians reptiles, which represented the highest type of animal life known at the close of the Paleozoic. The plant life also developed in a similar way. The sea weeds developed into land plants and these into shrubs and finally into large trees, which made great forests, but the highest form of vegetable life was far from representing the deciduous trees of today. From an economic standpoint the Paleozoic in Wyoming is of but little importance, the building material and the production of iron, oil and gas being the only products. In the east and in other countries, it was in the Paleozoic that the great Carboniferous coal fields were formed. Along the Appalachian mountains there are great fields of oil and gas, as well as beds of salt, clay, gypsum and iron ore. In the Mississippi valley these rocks contain vast deposits of lead and zinc. In Wyoming, this series, although very thin, must be considered as essential bands, since they are found extending to high points along the mountains and act not only as large storage reservoirs but also furnish hydrostatic pressure. Again they are important since the water found in them is usually quite free from alkali and other injurious ingredients.

CAMBRIAN PERIOD.

This was the first geological period in which life became of much importance on our earth. The records of the rocks prove conclusively that all life was confined to the sea, and was represented by lower forms of the animal and vegetable kingdoms. While deposits thousands of feet thick were collecting in the eastern part of the United States, Wyoming was dry land, but became partly submerged near the close of this period. There are no Cambrian rocks known in southeastern Wyoming; but in the central part and in the north and west, the strata reach a thickness of from a few hundred to about 1,000 feet. The lower portion of this series is made up of conglomerates and sandstones that are usually metamorphosed into quartzites; the upper is nearly all limestone. The later beds are exposed only in northern Wyoming, while the reddish sandstones, conglomerates and quartzites are exposed as far south as Rawlins and form the major part of the Cambrian northward into the Wind River and Big Horn mountains. These strata form the lowest bands in many of the artesian basins, since they rest either upon the Archean or upturned edges of the Algonkian rocks. This is a very important water-bearing formation and will probably be the greatest in any of the basins where the Cambrian rocks occur. They will usually be found encircling the Archæan masses, and typical exposures can be seen at Whalen canon, east of Sundance, northwest of Rawlins, along the Grand Canon of the Platte, near Miner's Delight, along the Big Horn and Wind River mountains.

PLATE I.



SOME CAMBRIAN FOSSILS SELECTED FROM VARIOUS SOURCES.

[Explanation of Plate I.]

No. 1—*Paradoxides bohemicus,* Barr.
No. 2—*Olenellus kjerulfi.*
No. 3—*Olenus truncatus,* Brisnn.
No. 4—*Holopea sweeti,* Whitfield.
No. 5—*Ophileta primordailis,* Whitfield.
5*a*—Side view of No. 5.
No. 6—*Bellerphon antiquatus,* Whitfield.
No. 7—*Orthis (Protorthis) billingsi,* Walcott.
No. 8—*Linnarssonia transversa,* Walcott.
No. 9—*Triplesia (Camarella) primordialis,* Walcott.
No. 10—*Lingulepis antiqua,* Hall.
No. 11—*Stenotheca arcadia,* Walcott.
No. 12—*Matheria variabilis,* Walcott.

THE ORDOVICIAN PERIOD.

(LOWER SILURIAN).

At the close of the Cambrian all of Wyoming was elevated above the sea and remained so for long periods of time; but the northern half of the state was submerged near the close of the Ordovician period, which allowed strata to accumulate to a thickness of from 600 to 900 feet. These rocks are light colored, thick bedded limestones and sandstones, but contain very little fossil life. The Ordovician period was one of great importance in geological history. Prior to this time the life was represented by sea life only and the highest types were invertebrates. During this period insects made their first appearance on the land and fishes in the sea. It was also marked by the general advancement of invertebrate life, and trilobites reached their maximum of development. Rocks of this period are found along the Wind River and Big Horn mountains, where they extend to points of considerable elevation. The strata, being sandstones and limestones, are of great importance in the vicinities where they occur, and are practically as valuable for artesian wells as the Cambrian. The supply of water will usually be large and will flow under great pressure. Good exposures of Ordovician can be seen two or three miles northeast of Miner's Delight, along Beaver creek, near the head of Warm Spring creek, a few miles above Dayton, and eight or ten miles west of Hartville. In Wyoming nothing of comercial importance has been found associating within these rocks except building material. In Ohio the Ordovician produces natural gas and petroleum.

SILURIAN PERIOD.

(UPPER SILURIAN).

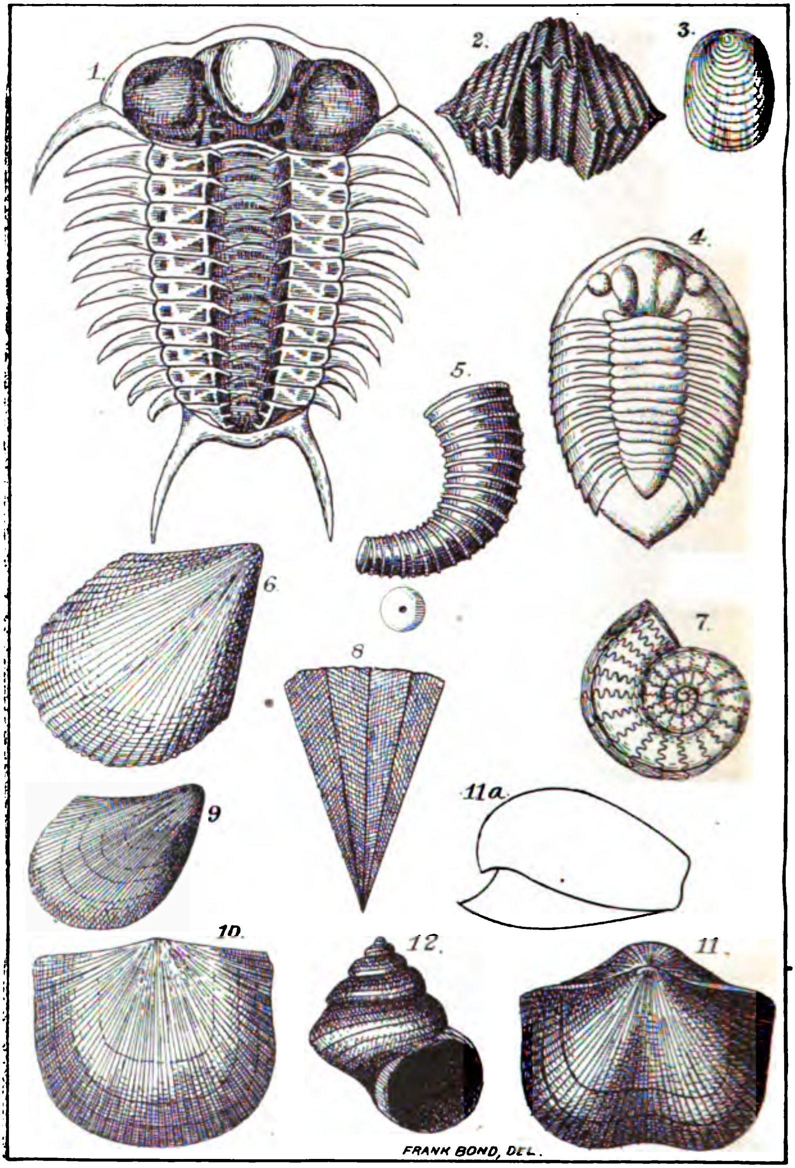
So far as known there are no Silurian rocks in Wyoming. Many geologists have reported the Silurian, and in the reports of Hayden the term is used. In the most of these cases the Cambrian was considered Silurian, together with the thin band of Ordovician or Lower Silurian. So far as our present investigations have proven, Wyoming was dry land during the Silurian, as it had been the greater portions of the Cambrian and Ordovician. Owing to the absence of the Silurian rocks, and slight importance of the Devonian, plates of fossils illustrating these periods have been omitted.

DEVONIAN PERIOD.

This is the "Old Red Sandstone" period. By others it has been called the age of fishes. It is only recently that the Devonian has been reported from this state, and all that is at present known of it is confined to the northwestern corner of Big Horn county and Yellowstone park. It is highly probable that thin bands may also be found in the Big Horn mountains. In the eastern part of the United States they attain a thickness of several thousand feet, while in Wyoming they are only 250 feet. The strata are chiefly limestones in which there are a few typical species of invertebrates. No fishes have been reported. In considering the many phases in geological history, there are numerous important events that should be recorded; but only a very brief reference will be made. Prior to this period we have little or no evidence that forests ever existed; but during the Devonian they were extensive enough to form veins of coal. Vertebrate life was introduced on land in the form of amphibians (frog-like animals). The seas were filled with fishes. At no other period in the world's history did so many fishes live. They were not like the most of the fish that we are acquainted with today, but belonged to an old type which is represented in our rivers by the sturgeon.

In Wyoming the Devonian rests conformably upon the Ordovician. Nothing of economic importance has been re-

PLATE II.



FRANK BOND, DEL.

SOME ORDOVICIAN FOSSILS.

[Explanation of Plate II.]

No. 1—*Ceraurus pleurexanthemus,* Walcott.
An Ordovician Trilobite.
No. 2—*Orthis (Platystrophia) biforata,* Hall.
No. 3—*Lingula quadrata,* Hall.
No. 4—*Lichas trentonensis,* Meek.
No. 5—*Crytoceras subanunlatum,* D'Orb.
No. 6—*Ambonychia radiata,* Hall.
No. 7—*Crytolites compressus,* Hall.
No. 8—*Conularia trentonensis,* Hall.
No. 9—*Ambonychia bellistrata,* Hall.
No. 10—*Rafinesquina alternata,* Meek.
No. 11—*Orthis occidentalis,* Hall.
No. 11*a*—*Orthis occidentalis,* Hall. Side view.
No. 12—*Cyclonema bilex,* Conrad.

ported from these strata; but in the east they supply both oil and gas, and in England they contain thin beds of coal. On account of the very limited occurrence these rocks enter into the structure of the Big Horn artesian basin only, and in this, in the northwestern corner, where the formations are nearly vertical along most of the outcrops. Consequently they deserve little or no attention. They will be found to be water-bearing and possibly there may be some tunnel propositions, where they may yield considerable water. Their high inclination practically bars them from furnishing wells.

CARBONIFEROUS PERIOD.

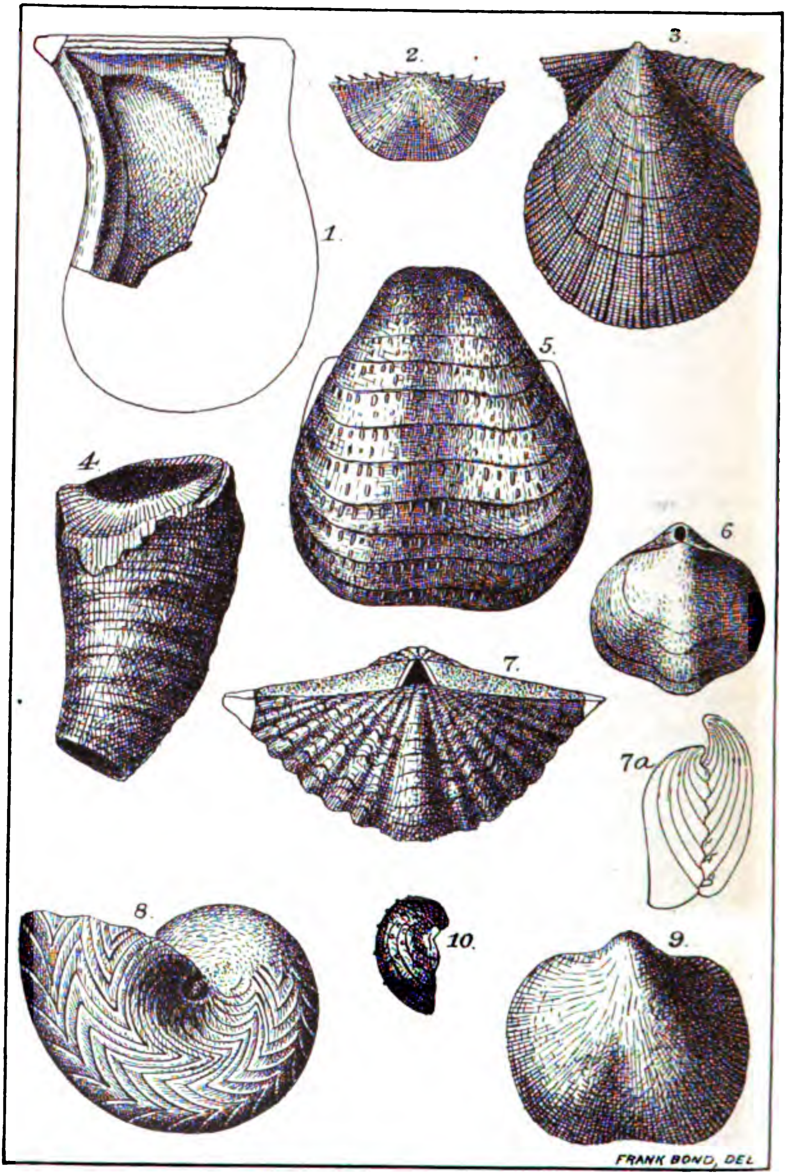
This period is separated into upper and lower divisions, both of which are represented in Wyoming; but neither is of much importance as compared with the Carboniferous formations of the Appalachian mountains. The lower Carboniferous series is formed only in the northern part of the state, where the strata are very thick bedded limestones. Near Miner's Delight there are strata of light colored limestone that are upwards of 50 feet in thickness. In the Wind River mountains this series of rocks has a thickness varying from 400 to 600 feet, but seem to thicken to the northward. The same series of beds have also been observed in the Black Hills and along the Big Horn range.

The upper Carboniferous marks a period in Wyoming geology in which the entire state with the exception of the Sweetwater valley was depressed and became a sea. Even the southeastern corner of the state, that had remained constant land since the close of the Archæan era, was submerged. This subsidence was quite late in the upper Carboniferous period and there are only thin bands of representative rocks, which are the first strata that are universally distributed in the artesian basins of Wyoming. In no instance have these rocks been reported to be over 2,200 feet in thickness, and this must be considered as the maximum if not an over-estimate. Usually the thickness is less than 1,000 feet. The strata are chiefly limestones with calcareous sandstone, and sandstones which vary in color from drab to pink and red. Along the Laramie mountains the lowest stratum is a grit and conglomerate, which has been considered to be Cambrian by some geologists; but there is no evidence to prove this suggestion.

The life of the Carboniferous shows an improvement on the life of the Devonian. The early forms of shell-fish that were so numerous in early Paleozoic periods have disappeared or are disappearing, and their places filled with higher and more complicated forms. Trilobites, that were the most common form of life during the Ordovician, have nearly disappeared at the close of the Carboniferous. The vertebrate life of the seas was made up of several types of fishes. Many of these were large sharks. The land vertebrates that are known were all amphibians; but in all probability reptiles sprang into existence at the close of the Carboniferous. The amphibians were of unusual size and were the kings of land life during this period.

The vegetable kingdom had advanced equally as rapidly as had the animal. The small forests of the Devonian merged into large ones during the lower Carboniferous and these into great jungles and vast forests during the upper Carboniferous. The last was the first great coal-making period, during which the great coal fields of central and eastern United States, England and many other countries were deposited. Conditions favored the rankest growth of vegetation at that time, which accumulated in the marshes where it had grown and was afterwards buried beneath the rocks and changed to coal. All of the trees of this period were lower types than the deciduous trees; many of them were similar to the ferns of our day. For example, the scouring rushes that grow along our

PLATE III.



SOME CARBONIFEROUS FOSSILS.

[Explanation of Plate III.]

No. 1—*Myalina subquadrata,* Shumard.
No. 2—*Chonetes granulifera,* Owen.
No. 3—*Aviculopectin occidentalis,* Shumard.
No. 4—*Zaphrentis stanburyi,* Hall. One-half natural size.
No. 5—*Productus nevadensis,* Meek.
No. 6—*Seminula argentia,* Hall.
No. 7—*Spirifernia pulchra,* Meek.
No. 7*a*—Side view of No. 7.
No. 8—*Goniatites goniolobus,* Meek.
No. 9—*Orthis resupinata,* Martin.
No. 10—*Productus longispinus,* Sowerby.

streams and are seldom over 18 inches or 2 feet in length, and a quarter of an inch in diameter, were large trees during the Carboniferous coal period. Besides the great accumulation of coal in the Carboniferous, there were beds of iron ore, fire clay as well as other clays, gypsum, salt, petroleum and gas. Petroleum is never found associated with coal veins. There are also deposits of lead and zinc ores in the lower Carboniferous of the Mississippi valley. In Wyoming the Carboniferous rocks in no way compare to the series in the east. They do not contain any coal, clay, salt beds, gypsum, lead or zinc, nor do they contain either oil or gas. The only valuable economic products thus far discovered have been iron and copper ore, together with building material. The great iron deposits at Rawlins and Hartville are found in these rocks, as are oxidized copper ores in the same regions. In a few localities there are beds of marble and marble onyx.

Since these rocks occur in every artesian basin in Wyoming and are thicker than any of the preceding formations, they are worthy of special consideration. In southeastern Wyoming the best wells will be found in these strata, and to the northward they will always be found to contain very valuable water bands. As a general rule water will be found at less depth than in the earlier formations. Especially is this true in localities where wells are to be drilled near the foot of the mountain, in the Triassic red sandstones. The supply of water will vary greatly with the localities; but as a rule it will be found very satisfactorily, and will also be excellent water for all purposes. Generally speaking, these rocks, with the Permian, form the lower slopes of nearly all of our mountain ranges.

THE PERMIAN PERIOD.

The Permian terrane is not well represented in America, and until recent years many have objected to referring any of the strata to this period. It was a usual thing for the geologists employed by Hayden to refer the highest bands of the Paleozoic of Wyoming to the Permian; but in no case did they offer any evidence for so doing. Later, no one considered any of these strata as Permian. Only a year ago I discovered along the flank of the Laramie mountains a formation, not over 200 feet in thickness, that contains a fauna almost the same as has been reported from the Kansas and Nebraska Permian. There seems little reason to doubt that these rocks are widely distributed and are to be found in the Big Horn and Wind River ranges, as well as in the southeastern corner of the state. The strata along the Laramie mountains are composed of light colored limestones, pink calcareous sandstones, light red sandstones and a bed of pure white sand that has been utilized for glass-making. It is possible that the rocks that have been assigned to the Upper Coal Measures may prove to be Permian. The presence of copper in the bands points that way.

During the Permian period of the world, the life resembled the Carboniferous. There were many lingering Coal Measure genera and a few species. There were also fossils that took on Mesozoic characteristics. The vertebrate life was not only represented by fishes and amphibians, but also by the introduction of reptiles.

The close of the Paleozoic was a mountain-making period and the Appalachian and many foreign ranges were made. In Wyoming there was no change or folding of the strata, and the great Paleozoic era passed into the Mesozoic era as uninterrupted as in many other instances one stage passed into another. Where Permian rocks are definitely known in Wyoming they all form the lower slopes of the mountain ranges and occasionally extend well up to the Archæan. Of the Paleozoic, these beds are of the least importance in the artesian basins. They are, however, superior to any of the Mesozoic.

Usually it will be possible to start a well in the Dakota sandstones, and pass through the Jurassic and Triassic and secure water in the Permian.

The Mesozoic Era.

Wyoming was a land mass during the greater portion of the Paleozoic era, and this accounts for the extremely thin beds of rock belonging to that grand division of geological time. At the close of the Paleozoic era, in the eastern part of the United States, the Appalachian mountains were made; but in Wyoming the Paleozoic seas merged into the Mesozoic without any interruptions, which causes the Mesozoic to rest upon the Paleozoic apparently conformably. It is very thick, from 20,000 to 30,000 feet. They differ from the older rocks in being less compact, and also in containing numerous bands of shale and clay. Although very thick, there are only a few bands containing limestone. Conditions had so changed that the seas were shallow and in some instances fresh water lakes covered vast areas. The changes in life were very important. In the early Mesozoic the vertebrate life had so advanced on earth that huge reptiles occupied both land and sea. The swimming saurians are known as *Plesiosaurs* and *Ichthyosaurs;* the land reptiles as *Dinosaurs.* Mammalian life was also introduced about this time; but the animals were about the size of a mouse and belonged to the lowest type. Our modern fishes also appeared during the early Mesozoic. Toward the middle of the Mesozoic, flying Saurians appeared, and also birds. It was about this time that the *Dinosaurs* reached their maximum development. Vegetable life was also advancing and in the upper portion of the era the first deciduous trees appeared on earth. At the close all of the

Plesiosaurs, Ichthyosaurs, as well as many other kinds of swimming Saurians, together with the *Dinosaurs* and *Pterosaurs* (or flying Saurians), became extinct. These rocks at one time covered nearly all of the state, and although great mountains have been made and hundreds of square miles of rock have been carried away by erosion, they cover or underlie three-fourths of Wyoming at the present time. They are found as the base of the mountains and occupying the valleys and forming the plateaus. They play an important part in the artesian basins of the state, since they are associated with all of them. At the close of the Mesozoic, the Rocky mountains were made and the mountain system that practically extends from Tierra del Fuego to Alaska came into existence.

THE TRIASSIC PERIOD.

This series has been called by other names than Trias, or Triassic. In the old world they are known as the "New Red Sandstone" and in Wyoming they have been called the "Red Beds." Of all the geological formations in Wyoming, this is the most conspicuous. It has numerous beds of dark red sandstone, with some red shales and thick beds of gypsum near the base. These bands can be seen at the foot of nearly all of the mountain ranges, either forming precipitous bluffs that rise a hundred or more feet, facing the range, or in dark red bands, following its trend. In some localities they have been nearly leveled by erosion, but can be seen cropping out at the crossing of every stream and in the red soil caused by their decomposition. They often color a wide band reddish that winds about the foot of the mountain like a great snake. Quite frequently these rocks are wind worn and cut into the most fantastic forms and are not easily surpassed for natural artistic beauty. In other regions there are deep circular depressions caused by caves in the Permian rocks below. This makes circular caves which are often one hundred feet in diameter and sometimes a hundred or more feet deep. These depressions are common in Crook county, east of Sundance, and near Spring creek, Big Horn county. Forming as this period does the base of the Mesozoic, they can easily be separated from the light colored sand and limestones of the Permian below, and the dark colored fossiliferous bands of the Jurassic above. No fossils have been recognized as in other sections, and the entire series is barren or nearly so, for not a single species of fossil of any kind has been reported from them. In other parts of the United States, and in Europe, they are rich in both plant and animal life and are especially marked by the introduction of swimming Saurians and mammals. The mammals were very small, probably not larger than a good-sized mouse. Good, and frequently bad, water will be found in the Triassic sandstones. The usual impurity is gypsum, which makes the water extremely hard and slightly bitter. While it is usually called poor water, it is nevertheless valuable for irrigation purposes. These sandstones will always furnish water in all of the artesian basins, but no one should expect to find a supply such as might be obtained in the Paleozoic rocks.

THE JURASSIC PERIOD.

Formely the Jurassic and Triassic terranes were united for the Rocky mountains under the head Jura-Trias. They are, however, so different in their general characteristics that a novice can easily draw the line of demarkation, and there is no reason why they should not be discussed as they are here, under different heads.

The Jurassic rocks are everywhere found resting upon the Triassic red sandstone, and are widely distributed throughout Wyoming. Of this series there are two distinct stages, the Shirley representing the marine and the Como the fresh water or upper division.

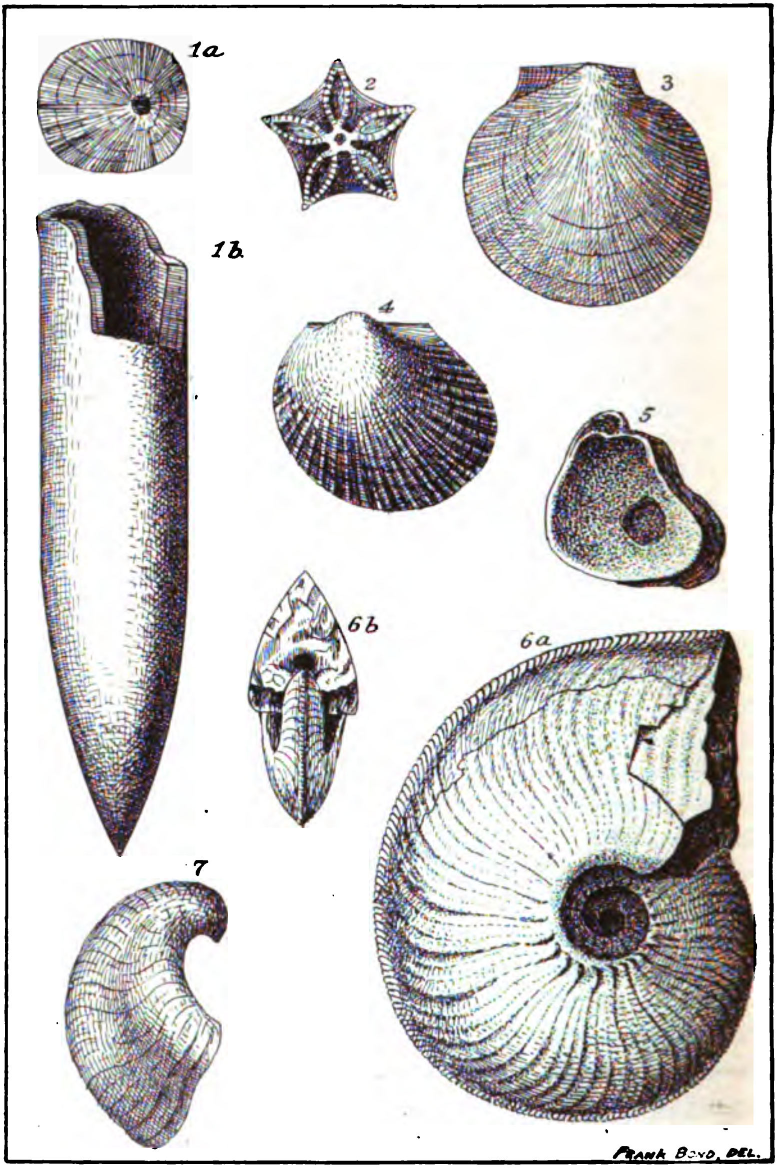
These stages represent a very small portion of the Jurassic time and should be considered as belonging to the upper third of the Jurassic rocks. In reality they represent only a fraction of this division.

THE SHIRLEY STAGE.

The Shirley stage is composed of bands of dark clays and shales, together with a few thin bands of dark colored limestones and numerous strata of sandstone. Near the base the sandstones are usually light colored. In thickness this stage varies from a few feet to 250 feet and probably exceeds this in the western part of Wyoming. In southeastern Wyoming this formation does not occur, the limit being between twenty-five and thirty miles northwest of Laramie. With the exception of southeastern Wyoming, the Shirley rests upon the Triassic, and often the light colored sandstones are found in contact with the red.

There is a single characteristic fossil that always accompanies these beds and it is scientifically known as a *Belemnite.* It is a rather slender fossil, circular in traverse section, and tapering gradually to a point. Sometimes there is a conical opening at the broad end, and in fact there always is when the fossil is complete. A large one is six inches long and three-fourths of an inch in diameter. Besides the *Belemnites* there were numerous invertebrates and swimming Saurians. The *Ichthyosaur* or fish Saurian was a reptile with a long, large head, no neck, a round body with four paddles, and a long, slim tail. They varied in length from 12 to 40 feet and were very ferocious animals, that subsisted entirely upon flesh. Associated with the *Ichthyosaurs* were many other types of swimming reptiles, chief of which were the *Plesiosaurs,* or Plesiosaur-like animals. These differed from the foregoing in having long necks and larger paddles. They attained a greater length and were also carnivorous in habit, and absolute rulers of the sea. The largest of the Plesiosaur type known was discovered in Wyoming. A front paddle in the University

PLATE IV.



FRANK BOND, DEL.

SOME JURASSIC FOSSILS FROM THE SHIRLEY STAGE.

[Explanation of Plate IV.]

No. 1*a*—*Belemnites densus,* Meek. Side view.

No. 1*b*—Transverse section of No. 1*a*.

No. 2—*Pentacrinus asteriscus,* Meek. Enlarged.

No. 3—*Camptonectes bellistriata,* Meek. One-half natural size.

No. 4—*Pseudomonotis curta,* Hall.

No. 5—*Ostrea strigilecula,* White.

No. 6*a*—*Cordioceras cordiformis,* M. & H. Much reduced. Side view.

No. 6*b*—*Cordioceras cordiformis,* M. & H. Much reduced. Profile view.

No. 7—*Gryphaea calceola,* var. ***nebrascensis,*** M. &. H. One-half natural size.

collection is nearly eight feet in length, and other parts in proportion. Associated with the land life, which was largely *Dinosaurs,* were numerous *Pterosaurs,* or flying reptiles, and a few birds that were provided with teeth. None of these have been found in Wyoming, but are associated with Jurassic rocks in other regions. In these seas there were also numerous fishes and turtles, and along the rivers many crocodiles.

THE COMO STAGE.

The Como stage at one time covered the entire state with one possible exception, and persists at the present, except in localities where mountain-making and folding have caused excessive erosion. These strata differ from the Shirley in being of fresh water origin, and hence they do not contain any marine life. This character alone will aid any one in separating them from the lower beds. The formation is from 150 to 250 feet in thickness, and above it there is nearly always a band of either Dakota conglomerate or sandstone, of the Cretaceous. It is a common thing to see the slopes of the Como, which are often quite precipitous, piled up with blocks of Dakota conglomerate, which range from a few feet to cubes 20 feet in diameter. The strata are largely marls and clays of different colors, with yellow, brown, red and drab predominating. These are separated by a few thin bands of sandstone and limestone.

The Como stage is the great *Dinosaur* horizon from which the many curious and huge animals have been collected. *Dinosaurs* represent the largest land animals that have ever lived, as well as very small ones. Wyoming is justly celebrated for these remains, since there is not another spot on earth where so many have been found. The largest of these animals were 80 to 90 feet in length and stood 20 to 25 feet high. A thigh bone in the University collection measures 69 inches high and the shaft is 33 inches in circumference.

A dorsal vertebra is 40 inches high and the centrum measures 12 inches in diameter. A rib is nearly seven feet long and is 14 inches in circumference.

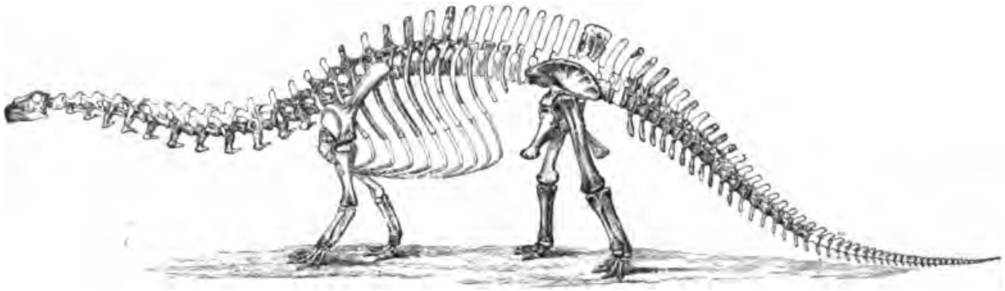
The largest animals were herbivorous quadrupeds; but others, which hopped about like a kangaroo, were carnivorous. Some had huge plates of bone ornamented with spikes; in fact, the life was too varied to even notice in a description of this sort. The bones of these animals are found in beds of marls and sanstones and sometimes occur in layers that are four feeet thick, and so mixed up that the most expert anatomist can not assemple them again.

With the marl beds there occur fresh water mollusks, some fishes and crocodiles. But little is known of the vegetable life. There are numerous species of petrified wood found and also some Cycad trunks. Cycads were an early form of vegetable life, the trunk of which grew about a foot in height and from six to ten inches in diameter. They are conical in form and are marked in the surface with many diamond-shaped leaf scars. Some twenty species have been found in the Como stage.

During this stage Wyoming was a low, marshy country, largely covered with fresh water lakes, about which grew a tropical vegetation. From an artesian standpoint this formation is of less importance than any of those previously discussed.

The marls and clays contain considerable sodium sulphate, which is often seen as a thin, efflorescent crust on the surface. Good water follows the sandstones, especially the light colored bands. Great precaution should be taken in drilling through the Jurassic, for the strata of clay and marls will produce caving of a very serious nature. The Jurassic, taken as a whole, will be encountered in drilling in every basin in Wyoming in case the well is located in the Dakota stage and is drilled to a depth of 1,000 feet or more.

PLATE V.



Brontosaurus excelsus, after Marsh. This animal, when alive, was 80 or 90 feet in length and lived in Wyoming during the Como stage of the Jurassic.

THE CRETACEOUS PERIOD.

The Cretaceous rocks of Wyoming belong to the upper half of the period, with the possible exception of some thin bands found in northern Wyoming, which may be lower Cretaceous. This is the greatest system of rocks of the state, for they cover or underlie over 50,000 square miles of territory. Taken as a whole, the stages are chiefly made up of sandstone, shales and clays, which reach the enormous thickness of from 20,000 to 25,000 feeet. The Cretaceous is to Wyoming what the Carboniferous is to Pennsylvania, if considered from an economical standpoint, for these rocks contain all of the coal known in the state and nearly all of the petroleum and natural gas.

Hayden studied the western Cretaceous along the Missouri river nearly half a century ago and made the following divisions:

	Thickness given.
Fox Hills	500 feet
Fort Pierre	700 "
Niobrara	200 "
Fort Benton	800 "
Dakota	400 "

Since these names were adopted there have been many changes in the meaning of some of them, and the introduction of new terms to take their places. For example, some of the geologists have included the Niobrara, Fort Pierre and Fox Hills under the name Fox Hills. Others have used Fort Pierre to represent the same band. The United States Geological survey have included the Fox Hills and Fort Pierre under the name Montana and the Fort Benton and Niobrara under the name Colorado, but retaining the original names given by Hayden, for lesser divisions. Following the work of Hayden along the Missouri river was the mountain investigation, and the Laramie stage was discovered. At present the Cretaceous divisions are as follows:

		Estimated Thickness. Maximum, in feet.
Laramie...	Fort Union?	2,000
	Laramie	5,000
Montana ..	Fox Hills	6,000
	Fort Pierre	7,000
Colorado..	Niobrara	2,000
	Fort Benton	2,000
Bear River		3,500
Dakota ...		1,000?

These stages, so far as known, are conformable with each other.

The geological history of the accumulation of this great series of rocks is intensely interesting, but can not be given in this connection.

Following the Jurassic, when the greatest Saurians lived, we find Saurians, and especially *Dinosaurs,* up to the close of the Laramie. The swimming Saurians, *Plesiosaurs* and *Mososaurs,* were also common; but disappeared from the face of the earth prior to the close of the Cretaceous. Birds that were introduced in the Jurassic became quite numerous in the Cretaceous; but the mammals made no advance. Plant life was very abundant, as the many bands of sandstone and shale containing impressions of leaves, as well as the numerous coal veins, demonstrate.

The invertebrate life was represented by numerous species which resembled the shell fish of today much more than the fauna of the Carboniferous period. The Cretaceous period of Wyoming opened under fresh-water lake conditions and closed in a similar manner, the lake being mostly fresh water but occasionally brackish at the close. Nearly all of Wyoming was originally covered with Cretaceous rocks during the coal-making period. Then dawned the period of mountain-making, which caused these strata, together with the underlying ones, to be bent into great folds, which are now the axes of our mountain ranges. During this period Wyoming was changed from a nearly level country, that was about sea level, to one of great mountains and valleys. Originally all of the prominent ranges were covered with from 10,000 to 30,000 feet of sedimentary rocks, which have been removed by erosion. The Cretaceous rocks are to be found encircling the mountain ranges and lesser folds. At one time they occupied the great valleys, as for example the Green river, Big Horn river, Wind river, Powder river, Platte river and Laramie river. In the Green, Wind and Big Horn basins large areas are covered with Tertiary sediment. Although the Cretaceous strata are so extensive, and very thick, they do not play a very important part in the artesian basins as water-bearing rocks. The Dakota will in all probability be the most desirable water-bearing zone, and from this upwards in the geological scale the bands gradually become of less importance. The stages will be taken up under their respective heads and their strata discussed.

THE DAKOTA STAGE.

Until recent years this has been considered the base of the Upper Cretaceous, but since the investigations of Dr. Ward in the Black Hills it has been separated into two stages, one representing the lowest member of the Upper Cretaceous and the other the highest horizon of the Lower Crectaceous. Since this distinction has not been worked out in Wyoming, it will be considered under the original meaning. The upper half of the Wyoming Dakota is made up of bands of dark clays and shales and a few thin layers of gray sandstone; the lower half of thick beds of conglomerate and sandstone. On the slopes below the beds there are angular blocks of conglomerate which usually rest in the Como stage, which vary from a few feet to twenty feet in diameter. The thickness of this stage varies considerable, but is never less than 200 feet and has local developments varying from 500 to 800 feet and possibly more Few fossils* have been reported from the Wy-

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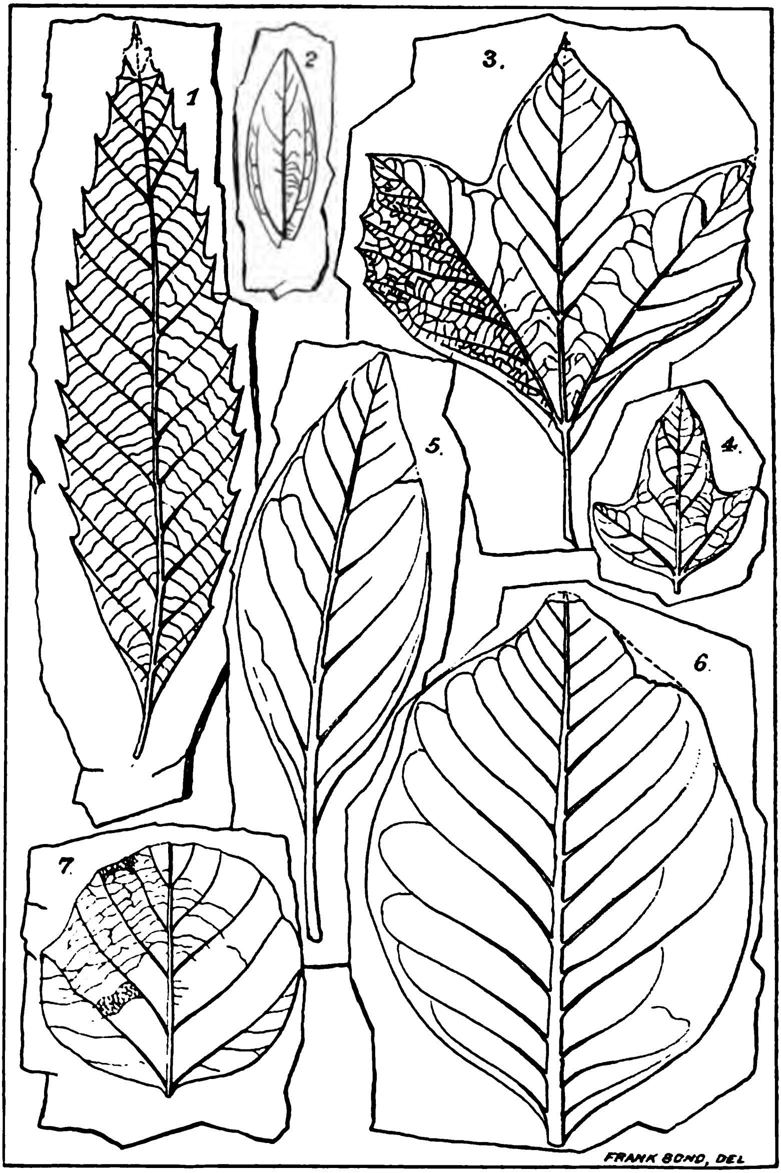
*Since writing the above I have found in the sandstones of the Dakota, in Johnson county, a small pelecypod. probably belonging to the genus *Nucula*.

PLATE VI.



CRETACEOUS.

SOME LARAMIE FOSSIL PLANTS.

[Explanation of Plate VI.]

No. 1—*Quercus primoidalis,* Lesqx.
No. 2—*Cinnamomum scheuchzeri,* Heer. One-half natural size.
No. 3—*Sassafras cretaceum,* Lesqx.
No. 4—*Sassafras mudgei,* Lesqx. One-half natural size.
No. 5—*Platanus recurvata,* Lesqx.
No. 6—*Juglans debeyana,* Lesqx.
No. 7—*Populites cyclophilla,* Heer? One-half natural size.

oming rocks and these have been found about the Black Hills in Wyoming, and are all plants. In these rocks are found the first evidence of deciduous trees in Wyoming. The formation can best be determined by its lithological character and its position in reference to the Como stage of the Jurassic and the overlying Fort Benton shales. This is the great water bearing horizon of the Dakota artesian basins and is also a conspicuous water horizon throughout Wyoming. Springs of excellent water are of common occurrence in these rocks along the mountains. Some attention should be paid to the fact that this is the second great petroleum horizon in Wyoming and that it also contains valuable veins of coal in Weston, Crook and Big Horn counties, and probably in many others. Along the Rattlensake, Powder River, Dutton, Belle Fourche, Bonanza and Beaver oil basins the Dakota will contain inferior water unless it is found in some of the upper sandstones above the oil. The rocks of this stage were deposited in fresh or brackish water.

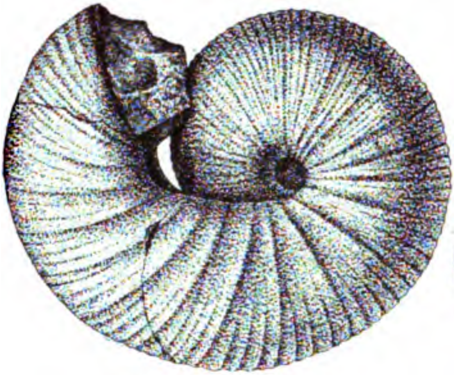
BEAR RIVER STAGE.

In southwestern Wyoming there is a formation that appears to be between the Dakota and the Fort Benton. It is characterized by an independent fauna and is coal bearing. It has been named the Bear River stage by the U. S. G. S. and it seems very probable that it is a distinct stage and should be included with the others of the Cretaceous. Some authors consider it a division of the Fort Benton. It has been found only in the southwestern part of the state and does not play an important part in our geology.

FORT BENTON STAGE.

Resting conformably, or nearly so, upon the Dakota of the eastern portion of Wyoming, is the Fort Benton. In the western half of the state the eastern limit of the Bear River has not been worked out, so that the Fort Benton can be considered as resting upon either the Dakota or Bear River stage. At the base of the Fort Benton there is always formed a very thick band of dark colored fissile shales, which weather nearly white. These shale beds are usually 200 feet in thickness, and if they are highly inclined the slopes are always covered with fragments of the shale bands. Associated with these beds there are numerous impressions of fish-scales, a few mollusks, and a few fish teeth. Above the shales there are prominent beds of dark clays and some shale bands that are nearly black, which are often mistaken for coal shales by eastern coal miners. In the dark clays there are masses of clay-iron stone that are nearly continuous, but not thick enough to be of commercial importance. In these clays are a few bands of Bentonite (a clay that has been called natural soap) which is destined to become a very important article of commerce. This clay is a hydrous, non-plastic variety which has an unusual power as an absorbent. The upper third of this stage is composed of sandstones and clays. The sandstones are usually of a light brown color and contain numerous fossil mollusks and sharks' teeth. The Fort Benton has a maximum thickness of at least 2,000 feet. Oil springs and natural gas vents have been found in several localities. As a water-bearing horizon it is very questionable. The clay beds contain an unusual amount of the sulphates of sodium and magnesium, and drilling will be found difficult on account of so many soft bands. The water supply will not be large. The upper half of the stage, when the sandstone bands are most numerous, will furnish the best water.

Typical exposures of the Fort Benton shale can be seen at the following localities: North of Hutton's lake, Albany county; at Brown's canon and Freezeout hills, Carbon county; a few miles east of Lander, in Fremont county; at Bonanza and



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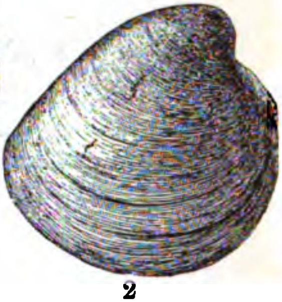

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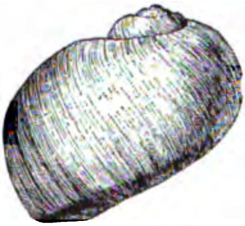

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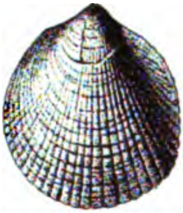

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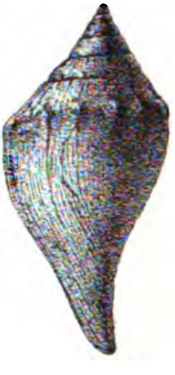

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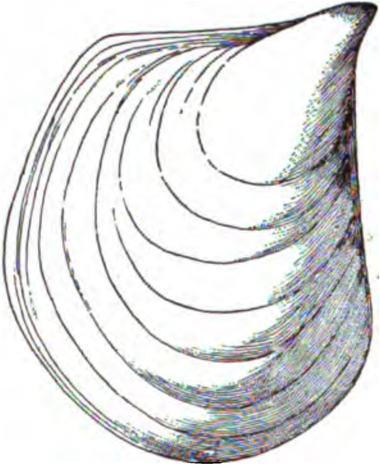

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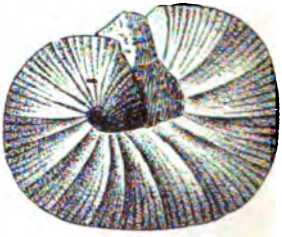


6

CRETACEOUS.

FORT BENTON FOSSILS.

[Explanation of Plate VII.]

These fossils are conditionally placed under the Fort Benton stage; realizing that the line between the Fort Benton and the Niobrara has not been finally fixed, and until this has been done we cannot say definitely what are Fort Benton and what are Niobrara fossils.

No. 1—*Scaphites ventricosus,* M. & H.
No. 2—*Cyrena securis,* Meek.
No. 3—*Gyrodes depressa,* Meek.
No. 4—*Cardium pauperculum,* Meek.
No. 5—*Fasciolaria (Crytorhyhis) utahensis,* Meek.
No. 6—*Scaphites warreni,* M. & H.
No. 7—*Inoceramus fragilis,* H. & M.

two miles west of Cody, Big Horn county; southwest of Dayton a mile or so, in Sheridan county; at the Belle Fourche oil field, in Crook county; at Newcastle, in Weston county; along the north side of the Laramie mountains, in Natrona and Converse counties, and along the east side of the same range in Laramie county.

THE NIOBRARA STAGE.

We know less of the rocks of this stage than any other one of prominence in Wyoming. This is due to the nature of the strata, which in the southeastern part of the state have near their base a thick bed of yellowish-white chalk. This has yielded so readily to erosion that it is seldom seen outcropping. For miles along the foot of a mountain range the chalk beds have been entirely covered with soil. The thickness of this stage approximates 2,000 feet. When the chalk beds are exposed it can be considered sufficient evidence of the stage, for there are no other beds of chalk known in Wyoming. In the Tertiaries there are whitish, soft bands that have been called chalk, such as the many chalk bluffs, hills and mountains; but none of these are chalk and some of them do not contain any carbonate of lime. Above the chalk beds the strata are clays and shales chiefly, with a few bands of sandstone. None of these bands contain many fossils, and all that have been reported are invertebrates. In Kansas they contain great swimming Saurians *(Plesiosaurs* and *Mososaurs*) and also early birds that were provided with teeth. So far, in the development of the mineral resources of the state, nothing of economic importance has been discovered in the Niobrara. There are a few beds of oil sand, and these together with the clays, shales and chalk beds, will prove to be of value in the future.

This stage is on a par with the Fort Benton, so far as artesian wells are concerned. Good water will be found in the sandstones and chalks, but the clays and shales contain a vast quantity of soluble salts that will render the water unfit for any purpose. While flowing wells will be found, the amount of water from any of the bands will not be large.

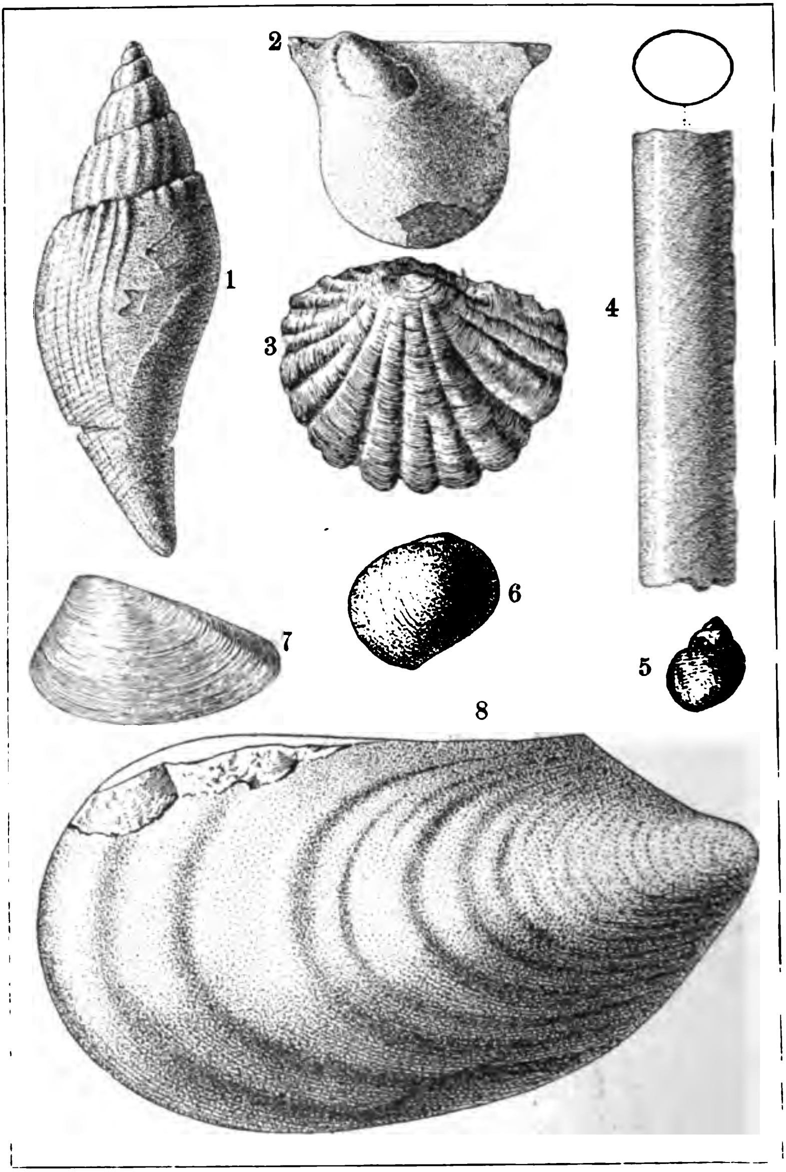
THE FORT PIERRE STAGE.

This is the thickest formation of the Rocky Mountain Cretaceous, having a maximum thickness of over 7,000 feet. It has been found along all of the Wyoming mountain ranges. The rocks of this stage are chiefly dark colored shales, which contain a few fossils, especially *Baculites*. The shales are in the lower half of the series and gradually change toward the top to bands of sandstone and clay. Near the top there are several bands of very fossiliferous sandstone. Besides the bands of sandstone there are strata made up of concretions of various sizes, ranging from a few inches to ten feet in diameter. Some of these concretions have been formed about a mass of invertebrates and when broken open contain specimens that have retained their irridescent luster and are the most beautiful of all Cretaceous fossils. While these concretions can be considered a valuable indication of the Fort Pierre, their presence can not be taken as absolute testimony, since there are concretions found in other Cretaceous stages. A few typical fossils associated with the concretions would furnish ample means for determining this stage.

The fossils associated with the Fort Pierre are numerous. There were many vertebrate animals, but few of these have been found in Wyoming. In the upper bands of sandstone there are many species of fossil plants. The invertebrate fossils, which are of greatest importance in identifying these rocks, are species of *Baculites, Inoceramus.*

Economically these strata are of considerable importance. Petroleum has been found in a few instances and probably the Salt Creek oil occurs in this stage. Coal has also been reported, but it is not definitely known that there are workable

PLATE VIII.



CRETACEOUS.

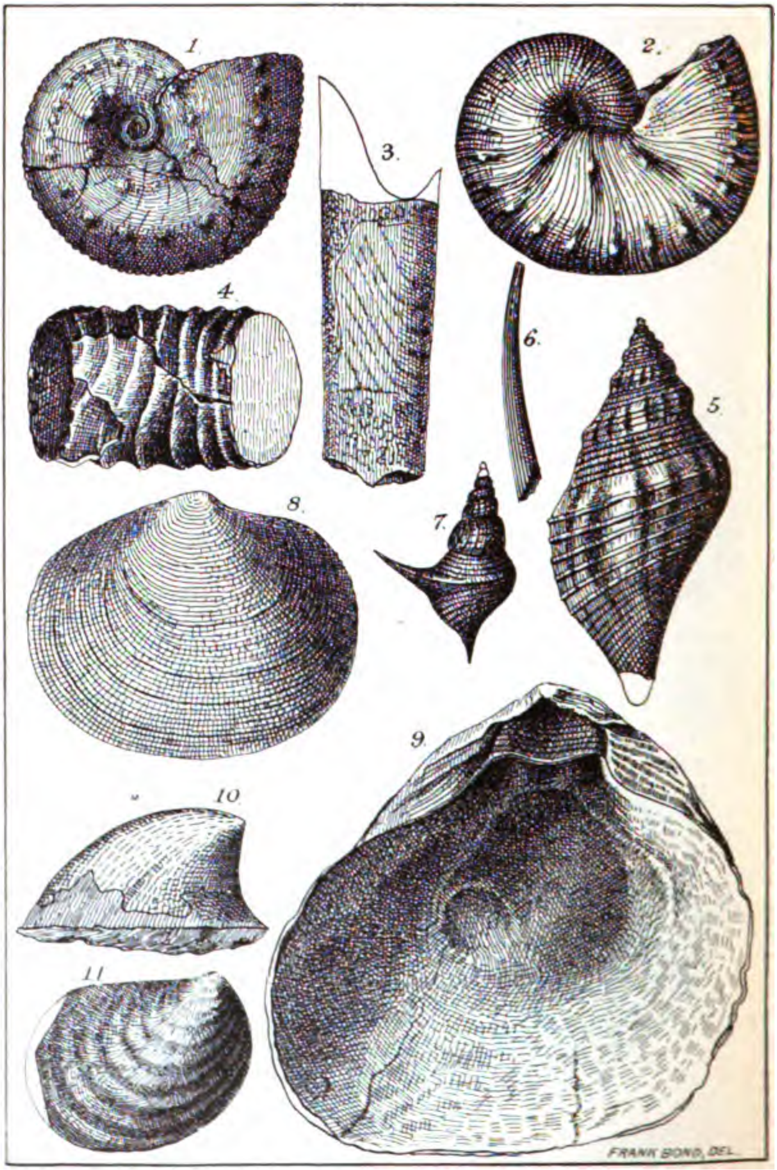
NIOBRARA FOSSILS.

[Explanation of Plate VIII.]

These fossils are conditionally referred to the Niobrara stage. Eventually they may be found to belong in part to the Fort Benton.

No. 1—*Rostellites ambigua,* Stanton.
No. 2—*Avicula gastrodes,* Meek.
No. 3—*Ostrea lugubris,* Conrad.
No. 4—*Baculites gracilis,* Schumard?
No. 5—*Lunatia concinna,* H. & M.?
No. 6—*Neritina pisum,* Meek.
No. 7—*Corbula sutrigonalis,* M. & H.
No. 8—*Inoceramus labiatus,* Schloth.

PLATE IX.



CRETACEOUS.

SOME FORT PIERRE FOSSILS.

[Explanation of Plate IX.]

No. 1—*Placenticeras placenta,* var. *intercalaris,* M. & H. One-fourth natural size.

No. 2—*Scaphites nodosus,* var. *brevis,* M. &. H. One-half natural size.

No. 3—*Baculites ovatus,* Say. Much reduced.

No. 4—*Heteroceras angulatum,* M. & H. From a fragment. One-half natural size.

No. 5—*Pyrifusus intertexus,* M. & H.

No. 6—*Dentalium gracile,* M. & H.

No. 7—*Anchuria nebrascensis,* E. & S.

No. 8—*Lucina occidentalis,* Morton.

No. 9—*Ostrea patina,* M. & H.

No. 10—*Anisomyon borealis,* M. & H.

No. 11—*Inoceramus cripsi,* var. *barabini,* Morton.

veins. Clay beds are very numerous, and all grades of clay are found, varying from that used for common brick to the best fire-brick clays.

On account of the enormous thickness of these strata, the formation is usually found in broads bands at the foot of the mountains. The sandstone strata alternating with bands of clay make the artesian conditions ideal, but the pressure will usually be found to be very slight. For this reason the Fort Pierre can not be considered as an important artesian well horizon. Again, the quality of the water is questionable. The shales contain vast quantities of soluble salts which in many instances make the water unfit for any use. Good water usually accompanies the sandstone unless found in the vicinity of coal and oil.

Typical Fort Pierre exposures can be seen north of Harpers, in Albany county; where the Cheyenne and Northern railroad crosses Horse creek, Laramie county; a few miles north of Ervay, Natrona county; west and south of Lander, west of Bonanza, and between Sheridan and the Big Horn mountains.

THE FOX HILL STAGE.

The Fox Hill and Fort Pierre stages are often combined under the name of Montana, but since these stages combined have a thickness of at least 12,000 feet, the terms Fox Hills and Fort Pierre include too great a thickness for a single stage and as soon as they are thoroughly known they will be further subdivided. The Fox Hills in Wyoming has a thickness of 5,000 feet, and probably there are local developments that will reach 6,000 feet. The strata resemble the upper portion of the Fort Pierre and are mostly bands of brown sandstone, alternating with dark clays and shales. Usually there are a few hundred feet of light colored sandstones near the base, and a very thick band of brown sandstone capping the formation. The sandstones are very fossiliferous and contain remains of vertebrates, invertebrates and plants. It was in this stage that the *Plesiosaurs* became extinct. The fossil leaves are quite remarkable. In the white sandstones near Harpers palm leaves have been discovered that have a diameter of twenty inches. The invertebrates resemble to a marked degree the Fort Pierre, but there is a sufficient difference to distinguish one stage from the other. The most common vertebrate fossils are species of *Baculites, Inoceramus, Ostrea, Anchuria, Scaphites, Nautilus* and *Pectunculus.*

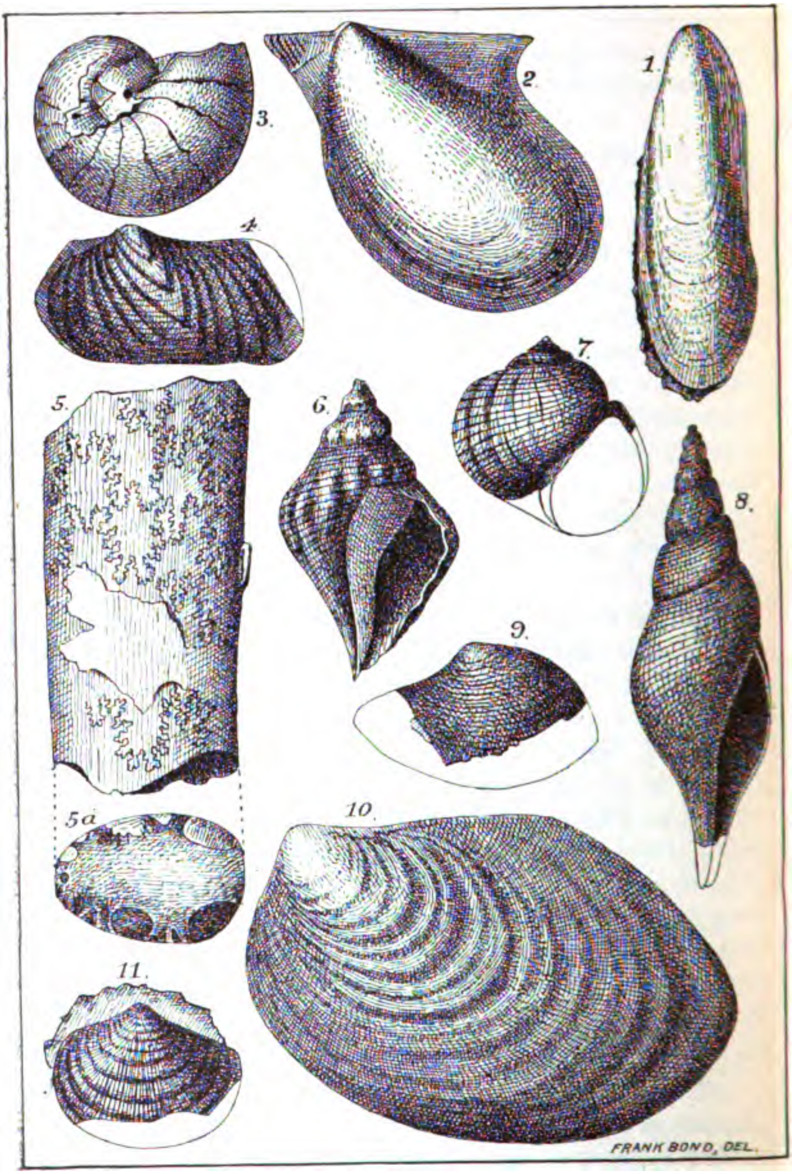
Economically this stage produces coal, oil, clay and building stone. Very valuable coal veins occur at Kemmerer, Diamondville and on the Laramie Plains and at several other points. Petroleum has been found in the Fox Hills along the Rattlesnake mountains. Typical exposures can be seen at Harpers, Kemmerer, below Bonanza, above Dayton, south of Fort Steele and at the southern base of the Seminoe mountains.

While the water found in the Fox Hills sandstones is usually superior to the Fort Pierre, yet it is not ideal. It can be relied upon as a water-bearing formation, but wells drilled in these strata will seldom yield a large supply of water. The reason for this is the same as given in the Fort Pierre—there is little or no head, and also the water supply is very limited on account of the distance from the mountains and the slight precipitation. Wells drilled in coal and oil belts may be considered as almost worthless. At Almond a well 1,000 feet deep produces water highly charged with sulphuretted hydrogen. When first drawn it is unbearable, but after standing it is used for domestic purposes and also largely for locomotive work.

THE LARAMIE STAGE.

This is the closing stage of the Cretaceous period, and is also the great coal formation of the Rocky mountain region. Owing to its wide distribution, and variations lithologically,

PLATE X.



FRANK BOND, DEL.

CRETACEOUS.

SOME FOX HILLS FOSSILS.

[Explanation of Plate X.]

No. 1—*Volsella attenuata,* M. & H.
No. 2—*Pteria linguiformis,* var. *subgibbosa,* M. & H.
No. 3—*Nautilus dekayi,* Morton.
No. 4—*Goniomya americana,* M. & H.
No. 5—*Baculites ovatus,* Say. Much reduced.
No. 6—*Cinuli concinanna,* H. & M.
No. 7—*Vanikoropsis tuomeyana,* M. & H.
No. 8—*Fasciolaria culbertsoni,* M. & H.
No. 9—*Tancredia americana,* M. & H.
No. 10—*Inoceramus cripsii,* var. *subcompressus,* M. & H.
No. 11—*Liopistha (Cymella) undata,* M. & H.

this vast accumulation of sediment, which is about one mile in thickness, has not been satisfactorily subdivided into lesser divisions. This will be done when the stage has been thoroughly worked over. At present it will be sufficient to suggest that there are upper and lower divisions, the upper, probably equivalent to the Fort Union* stage of early writers, containing the lignite coal veins, and the lower containing bituminous coal, as can be seen at the coal mines at Rock Springs and elsewhere. The strata of the entire stage are made up of sandstones, clays, shales and coal. The sandstones are usually friable, often thick bedded, and vary in color from light gray to dark brown. The clays are in great variety and are usually of a drab color. The shales are soft and friable.

Coal seams are numerous, and in some localities there are not less than 100 veins which vary in thickness from a few inches to 10, 20 and 40 feet. At Ham's Fork, Uinta county, there is a vein of coal 86 feet thick without a parting. Usually there are from six to ten workable veins in a field.

These rocks were deposited in fresh and brackish water and contain an abundance of fossils. Usually there are bands of shale or shaley sandstone associated with the coal veins that contain vast numbers of fossil deciduous leaves. There are also strata that are from six to twelve feet in thickness that are made up of oyster shells. There are also many other invertebrate fossils, especially many species of *Unio* (the common fresh water clam). With this life there are many species of land vertebrates. Chief among these were some large

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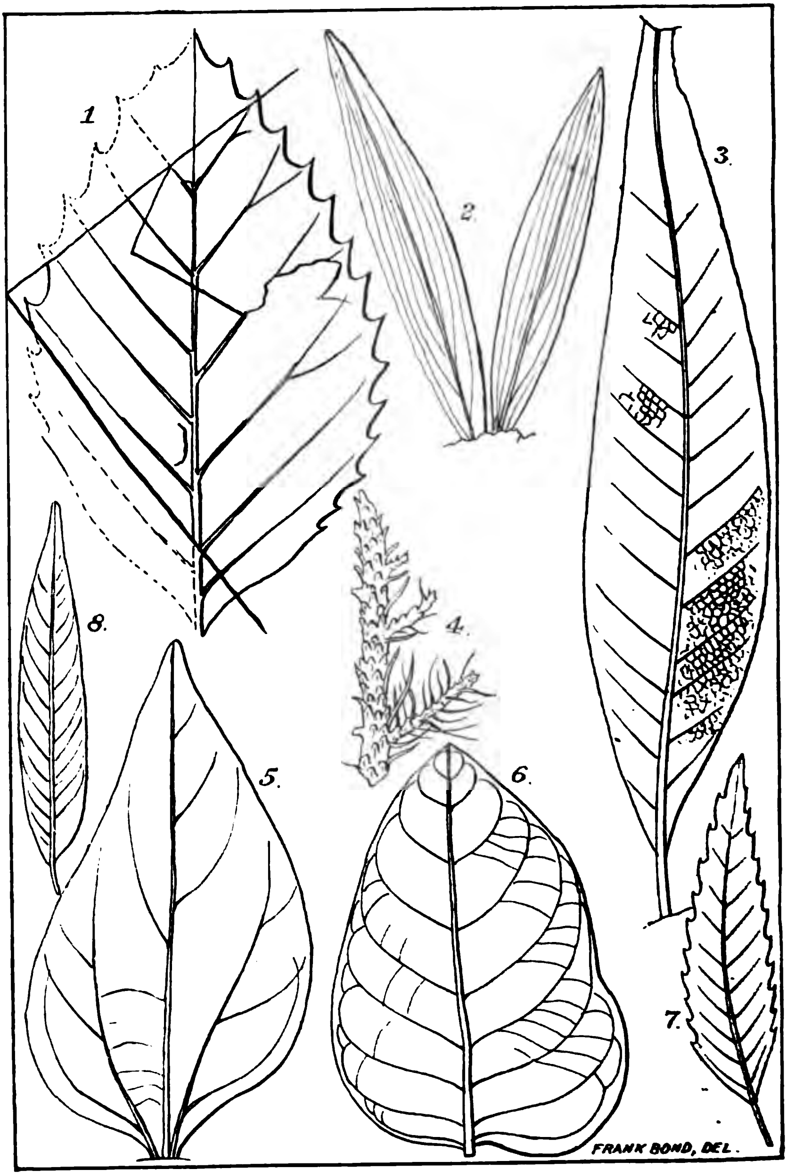
*Many geologists will object to my placing the Fort Union beds in the Laramie. They were so considered by many of the early geologists, who have had an opportunity to study the Fort Union formation in the field as well as to study the fossil remains. The paleobotanists have practically agreed that this formation is Eocene. I should like to see a consensus of opinions from all branches of paleontology, before this formation is finally considered to belong to the Cenozoic era. One point worthy of consideration in connection with this problem is the fact that, thus far in the study of this formation, no one has reported a mammalian fauna. It would seem that if snch exists there has already been sufficient field work done to discover it. If it ever existed during the deposition of the Fort Union sediments, there is no reason why some of the remains should not be present, for these beds are as favorable to the preservation of fossil remains as any other formation in the west. The presence of both plant and invertebrate remains is ample evidence on this point. Without the presence of a mammalian fauna, I would prefer to consider the Fort Union the highest member of the Cretaceous.

Dinosaurs. The largest one was much larger than an elephant and had a large head provided with three horns. These horns were located above the eyes and on the end of the nose. The remains of this huge creature have been found in great abundance in Converse county. There were also several other kinds of *Dinosaurs* living at this time, but they all became extinct at the close of the Laramie. There were also many species of very small mammals.

The Laramie formation is found in every county in Wyoming. The towns of Sheridan, Buffalo, Douglas, Glenrock, Carbon, Hanna, Black Buttes, Rock Springs and Meeteetse are located on these rocks. From Douglas one can go north to the Montana line and walk all the way on the Laramie coal measures. They cover nearly all of the Powder River valley, extending westward to the Big Horn mountains. The most of the coal mined in Wyoming comes from the Laramie rocks; in fact, they cover or extend beneath one-half of this state. At the close of this stage the Rocky mountains were made. Prior to this period Wyoming had been either a sea or a low land mass for geological ages; now these rocks were folded by lateral pressure and the folds soon emerged into long ranges like the Big Horn,Wind River and Medicine Bow mountains. The mountain-making caused many changes. The low swamps of the Laramie were converted into broad valleys and high mountain ranges. This change was sufficient to cause the disappearance of nearly all of the forms of life that inhabited Wyoming during the Laramie stage. It also caused a marked change in the climate, which affected the life and formed such basins as the Green River and Big Horn, which were cut off from the sea and which were, in the following stage, large fresh water lakes. The Laramie not only marks the closing of the Cretaceous system but also of the Mesozoic era.

This formation is also the last one in the ascending geo-

PLATE XI.



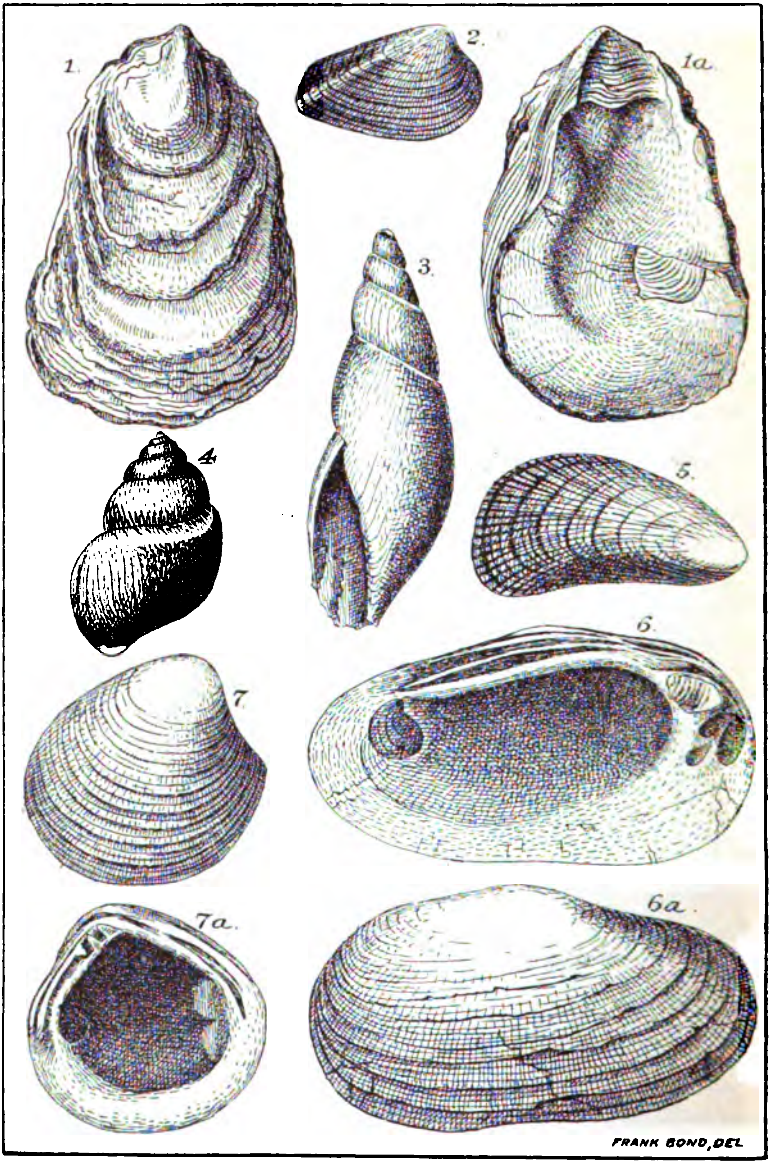
CRETACEOUS.

SOME LARAMIE FOSSIL PLANTS.

[Explanation of Plate XI.]

No. 1—*Quercus drymeja,* Ung.
No. 2—*Eucalyptus haeringiana,?* Ett.
No. 3—*Ficus lanceolata,* Heer.
No. 4—*Sequoia biformis,* Lesqx.
No. 5—*Cinnamomum affine,* Lesqx.
No. 6—*Apeibopsis discolor,* Lesqx.
No. 7—*Cillicoma microphylla?* Ett.
No. 8—*Salix angusta,* Al. Br.

PLATE XII.



SOME TYPICAL FOSSILS FROM THE LARAMIE STAGE.

[Explanation of Plate XII.]

No. 1—*Ostrea glabra,* M. & H.
No. 1*a*—*Ostrea glabra,* interior view.
No. 2—*Corbula subtrigonalis,* M. & H.
No. 3—*Bulinus atavus,* White.
No. 4—*Viviparus cousi,* White.
No. 5—*Volsella regularis,* White.
No. 6—*Unio danae,* M. & H.
No. 7—*Corbula cleburni,* White.
No. 7*a*—*Corbula cleburni,* interior view.

Note.—No. 4 on the opposite plate is in all probability a species of fresh water mollusk that belongs to the Bear River stage, but has often been referred to the Laramie. It was a mistake in placing it with the typical Laramie fossils, and should be eliminated.

logical scale in which artesian wells may be looked for, and in this the conditions are not favorable for important wells or for good water. Generally speaking, the base of the Laramie strata is a considerable distance from the mountains and the water supply is very limited. The dip of the formation along most of the ranges is slight, and there is not sufficient elevation of the lower bands to produce very much pressure. On account of the coal, all of the water coming in contact with coal veins is very poor. It is unfit for man or beast and is very often so charged with salts of soda and magnesium as to render it unfit for irrigation. Small flowing wells will be found about nearly all of the basins. Already wells have been drilled in the Laramie at numerous places and there are flowing wells at Rock Springs and Buffalo. The water at Buffalo is very good and at Rock Springs very poor.

Cenozoic Era.

After the completion of the Rocky Mountain uplift, and when the ranges were covered with sedimentary rock to a thickness varying from 10,000 to 25,000 feet, the Cenozoic era dawned. The changes wrought since the commencement of mountain making were so vast that neither land nor sea corresponded in any way to the previous condition. The life also changed so as to form a great break in its development. This break has not been, and possibly may never be, accounted for. The Mesozoic was the age of reptiles, but there are comparatively few found in the Cenozoic, and mammals replace them. The largest mammal known in the Cretaceous was not larger than a rat, but in the Cenozoic basins, at the very bottom of the strata, are found large mammals, and in the Eocene period they are found of elephantine size. The Cenozoic has been, and probably always will be, known as the age of mammals. In these strata are found the ancestral types of our modern animals, such as the horse, wolves, camels, cats, deer, rhinoceros and monkeys, together with a wonderful fauna that has long been extinct. In Wyoming, the early Cenozoic formations are confined to the basins that were made by the great folds which produced the mountains, such as the Big Horn, Wind River and Owl Creek ranges. Later these become dry and the Cenozoic fresh water lakes extend from the Laramie mountains eastward into Nebraska and Dakota. The sediment deposited was largely clay, sand and shale, which seldom formed a hard rock. Since these beds were deposited after the mountain making, they are unconformable with the Mesozoic, the Mesozoic usually dipping from 10 to 80 degrees and the Cenozoic lying nearly horizontal upon the upturned edges. This great unconformability is the only very marked one in the Rocky Mountain geology above the great unconformability between the Algonkian and Cambrian, and in all cases will serve as a guide to separate the rocks of the Cenozoic and Mesozoic eras.

Another characteristic feature is the almost universal "bad land" topography, typical examples of which can be seen in Goshen Hole, Bates Hole, Big Horn Basin, Green River Basin and north of the Rattlesnake range. The "bad lands" are usually sections almost devoid of vegetation, with narrow, deep gulches, which are often small canons, bounded by great walls that are nearly vertical, and culminating in tower and castle-like formations. Now and then these castellated terraces merge into imaginary crumbling cities and villages and make some of the most fascinating scenery in the state. There are also many places where the water has burst forth from the base of a high bluff and caused a great cavern leading backwards and upwards to open into the soft rock to the surface. These caverns are sometimes two or three hundred feet in length and are large enough to admit a man. They are caused by the water settling on the surface and coming in contact with the sandy formation, causing it to flow like a stream of very soft mud.

Following the Tertiary period of the Cenozoic was the Pleistocene, in which great changes were wrought. The climate of North America, as well as of the Orient, suddenly changed, and great ice sheets commenced to accumulate in the north and move southward. This was the glacial period, and the ice sheet extended as far south in the eastern part of the United States, as the Ohio river, but not nearly so far in the west. These conditions changed everything. The animal life that could not or did not migrate became extinct. The flora and fauna disappeared. Following this period of devastation was one of the retreat of the glaciers and the establishment of modern conditions.

The Cenozoic formations do not enter into any of the artesian basins of the state as important factors; but slight flows of water may be found in them. In many instances Tertiary rocks have completely covered thousands of square miles of earlier strata, which otherwise would have been productive territory. In a few places it will be found advisable to pierce the Tertiary where it is thin and secure artesian water in the earlier rocks. For example, along the south side of the Big Horn range, near Lost Cabin, near Oregon Buttes and in Goshen Hole.

THE TERTIARY PERIOD.

CLASSIFICATION OF WYOMING TERTIARY.

			Thickness of stages in feet.
TERTIARY.	Pliocene?		
	Miocene	Loup Fork	500
	Oligocene.	White River	1500?
	Eocene	Bridger	1500?
		Green River	1000
		Wasatch	1000

The Eocene formations of Wyoming are confined chiefly to the Green River, the Wind River and Big Horn basins, which were fresh water lakes during the early and middle Eocene stages. While these lakes were in existence there were Tertiary Eocene seas in which sediments were being deposited, along the southeastern coast of the United States and also along the Pacific Coast region, as well as at numerous other places in the world. The earliest stage of the Eocene which occurs, so far as known, has been found only in New Mexico, and is called the Puerco.

THE WASATCH STAGE.

In Wyoming the Wasatch is the earliest representative of the Eocene and is composed of variegated beds of clay and sand with occasional bands of sandstone. The clays are of a dark red, shading into pink, and in places yellow and brown. The sands are light colored and so soft that a rain storm will cause them to run like a stream of water. This is the lowest Tertiary formation of both the Green River and Big Horn basins, and has a thickness of about 1,000 feet. Estimates have been made that placed the thickness of the Wasatch at from 3,000 to 4,000 feet, but I have been unable to confirm these. This stage is characterized by the remains of many turtles, crocodiles and mammals. Some of the latter were very large, almost of elephantine size, but a description in a brief way would draw out this section to an unreasonable length, since mammals were the dominant life.

THE GREEN RIVER STAGE.

The Green River rocks differ entirely from the Wasatch, and they also differ in the kinds of fossils found. A typical section of the Green River stage is exposed at Green River, on the Union Pacific railroad. The rocks are shales or shaley sandstones capped with a thick band of brown sandstone. The shales are mostly bituminous, and there are bands that contain as high as 45 per cent of gas and oil. In many localities the shales are found in very thin layers, and the bedding has been so perfect that they separate into large plates that are from a quarter of an inch to an inch in thickness. The surfaces of these plates are so smooth that they may some day be of commercial importance. The thickness of this series has also been greatly overestimated by early geologists, and it is more than likely that it does not attain a thickness at any place of over 1,000 feet. Besides being made up of shales, they also have many other peculiarities that will aid in identifying them. These shale beds contain many petrified fish, which are so perfect and remarkable that they are known the world over. The fish are closely related to the modern forms and vary in size from a few inches in length to five and a half feet, and when taken out and properly cleaned, the remains are a mahogany color set upon a slab of creamy white shale. Besides the fish there are found insects, birds, leaves and crocodiles.

It is worthy of special note that no mammalian remains have ever been discovered in this formation.

THE BRIDGER STAGE.

The Bridger stage rests upon the Green River shale and the strata are variegated clays, sands and sandstones. The clays near the base of the stage are a vermillion red and shade into or alternate with lighter colored bands. Toward the top the rocks change into bands of sandstone and clays and often quite thick beds of breccias and conglomerates. It exceeds either of the previous stages in thickness, but absolute measurements are not at hand. The greatest area of Bridger is in southwestern Wyoming, but there are important escarpments in the Wind River basin and Red desert.

The fossils consist of a few fresh-water invertebrates, and monkeys, carnivors, insectivors, ungulates, rodents, birds, turtles, snakes, crocodiles and some large types of mammal life.

The Bridger represents the closing stage of the Eocene in Wyoming, but to the southward and across the Uinta mountains there is yet another stage known as the Uinta, which represents the highest horizon of the Eocene in the mountain region. This group might have covered a portion of southwestern Wyoming during the Miocene and Pliocene times, but was too soft to withstand the great erosion. At the close of the Eocene the basins in which the sediment had been accumulating drained, the Green river draining the southern basin and the Big Horn draining the Big Horn and Wind River basins.

OLIGOCENE STAGE.

There was, however, a great fresh water lake being formed to the eastward of the Laramie mountains and the Black Hills, and in this sediment continued to form.

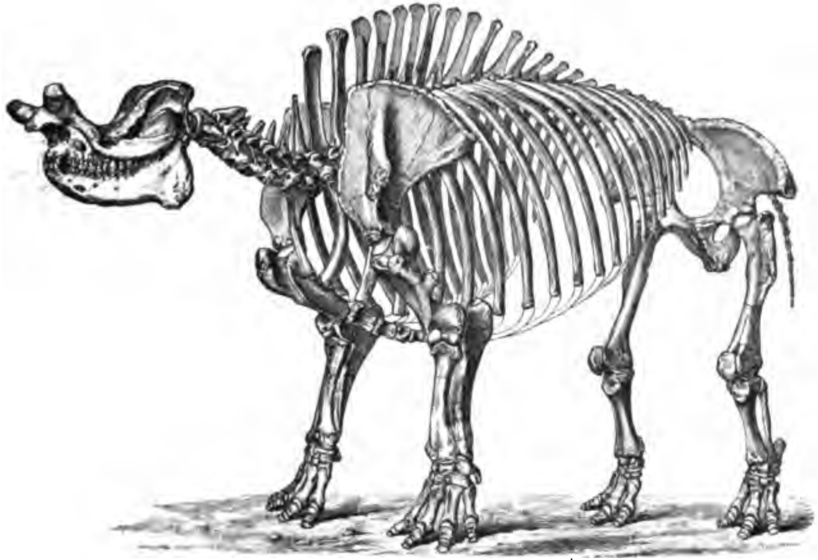
The lowest stage of this lake is known as the Oligocene, and beds are usually called the White River formation. They are largely clays and sands and weather into the typical "bad lands." There are only slight exposures of the Oligocene in Wyoming, since the strata have been covered with Miocene, and unless this covering has been removed the only exposures are found at the base of the Miocene bluffs, where the Oligocene rests upon the Cretaceous. The best exposures are found in Converse county, along the tributaries of the Cheyenne river, and in Bates Hole. The beds vary in thickness from 300 to 500 or more feet. In other localities there are numerous invertebrate fossils and also a flora, but in Wyoming these are absent. The life found in the Oligocene in this state is chiefly mammalian. There were also numerous turtles and a few crocodiles. Carnivorous animals were numerous and were represented by several types, especially cats. The three-toed horses were common. There were many animals that belong to the rodents (gnawing animals). The largest animal was the huge *Titanotherium*, which was herbivorous and nearly as large as an elephant.

THE MIOCENE STAGE.

The Oligocene and Miocene were practically deposited in the same basin, the Miocene representing the last stage in the history of the great fresh lake. The Miocene rocks are chiefly light colored and in southeastern Wyoming they are capped with a thick bed of conglomerate which extends eastward into Nebraska. The strata are quite soft and easily eroded into picturesque columns and spires, which are so well developed in the "band lands." The Miocene rocks have their greatest development east of the Laramie mountains, where they approximate 1,500 feet in thickness. They are also known in the Yellowstone park and in the Saratoga valley.

Life was very abundant. In the Yellowstone park a large flora has been discovered that is very much like the plants of today. Deciduous trees were numerous. Among the mammals which were very common were wolves and tigers of very ferocious types, camels, horses, mastodons, elephants (primitive), and rhinoceroses, the remains of which are common in the Wyoming formation.

PLATE XIII.



Titanotherium robustum, after Marsh. This was an animal of elephantine size that lived in vast numbers in Wyoming during the Oligocene of the Tertiary.

THE PLIOCENE STAGE.

This epoch is in all probability absent in Wyoming. Early writers referred the beds east of the Laramie mountains to Pliocene, but it is definitely known that these are Miocene.

This was the culminating epoch of the Tertiary and practically introduced the types of animals that we are familiar with today.

THE PLEISTOCENE PERIOD.

The Pleistocene or Quarternary represents recent geological time. Man was probably born on earth at the commencement of this period. The interior fresh water lakes had been drained and elevated during the Pliocene epoch, and Wyoming was no longer composed of high mountain ranges separated by beautiful fresh-water lakes, about which were magnificent forests that were swarming with the greatest variety of mammalian life. Conditions changed when the whole state was elevated some three or four thousand feet, which caused it to become an arid plateau. Our mountain ranges were very different from what they are today, since they were very much higher, probably over 5,000 feet above the present elevations. The valleys were also higher and the great deep canons had not been hewn out of rock.

The commencement of the Pleistocene was marked by the glaciation of the greater part of North America, the great ice sheet extending down to the Ohio river and as far west as eastern Kansas; thence northwest to British America. In Wyoming glaciers existed at the same time, but they were of the Alpine type and did not move down the mountain slopes and fill the large valleys. Glaciers were numerous in the Wind River mountains, the Yellowstone park, the Absaroka, the Shoshone mountains, the Big Horn and Medicine Bow mountains. Glaciers also reached the Wyoming line from the Uinta mountains, in the southwestern part of the state. At present there are a few small remnants of these glaciers in our highest mountains. The glacial period comprised many intervals in the eastern part of the country, but no divisions have been discovered in Wyoming. The first stage of the Pleistocene was one of grinding down the high mountain ranges, of leveling rough country, and the second of covering the rocks with soil, and later by establishing perfect drainage systems and perfecting climatic conditions, which was preparing it for the use of man. During the first part of this period the hairy mammoth and mastodon lived, and with them horses, bison, bears, wolves, tigers and numerous other animals. Not many of the early Pleistocene animals have been found in Wyoming, but no doubt there are vast fields that will yet reward the persevering scientist. The remains of elephants have already been discovered and in some of the caves numerous animals will probably be found that belong to this very period.

This terminates the geological sketch. It has been exceedingly brief, but it is hoped that enough has been said to enable the citizens of this state to decipher, in part at least, the geology about their own homes and to utilize this information in studying the questions pertaining to artesian basins.

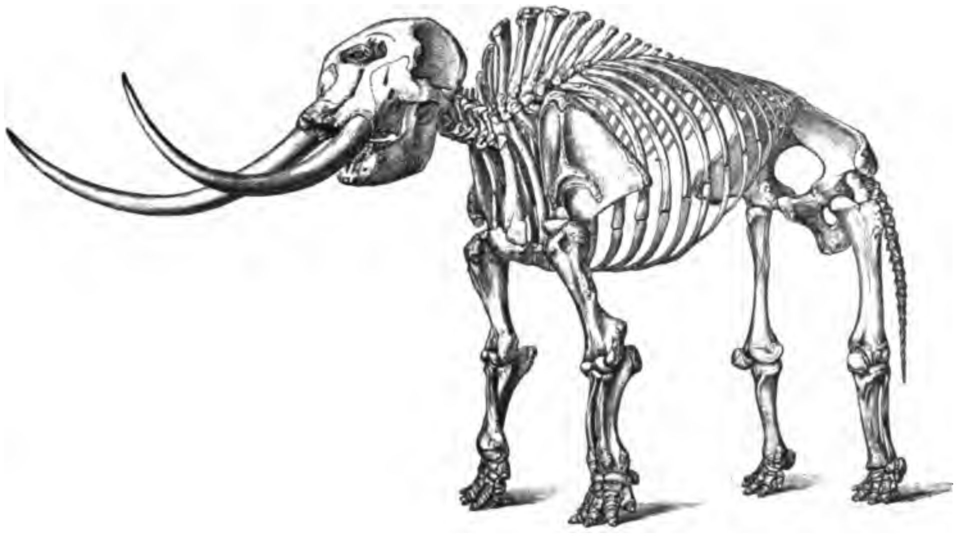
There is one other matter that should be referred to. The lessons taught in the study of geology are indeed many and as a rule they present many interesting phases. In reading or studying geology, consider these few points at least.

This world of ours has not always existed; that it has in some very remote age been created. That originally there was no life on this sphere—that life was born and at the first it was extremely simple; but as geological ages rolled by it became more and more complicated until finally man appeared as the culminating event.

The subject of historical geology deals with the development of life as the records are found in the rocks. In fact, it is the history of the world's development. The history had for its author the Creator and Ruler of this universe—a history written by God Himself, undefiled and undefilable by man.

To those who are interested in the study of geology and wish to perfect themselves in the science, I respectfully refer them to the text-books published by Dana, LeConte and Scott.

PLATE XIV.



Mastodon americanus, Cuvier. The largest mammal that lived during the Pleistocene. Very common in America.

Water-Bearing Zones.

All formations have water-bearing zones under favorable conditions. Drill a well where one will, and at some depth water will be found. The water zones that are to be discussed under this head are the favorable formations in the artesian basins of Wyoming. Sometimes a whole formation contains water, while on the other hand only a single band may be productive. Porous rocks of any kind between two impervious strata form the ideal condition, hence sandstones are often known as water-bearing rocks. Besides being porous, it is necessary for the stratum to have a greater water supply than the rainfall furnishes, in the arid regions, before it can be worthy of consideration In an artesian basin there are two principal ways in which the stratum may gather a water supply. The most important sources are found high up along the ranges, where the precipitation is much in excess of that of the valleys, and where the melting snows constantly feed the stratum so long as the snow lasts. The elevation of the stratum not only provides it with a supply of water, but also furnishes hydrostatic pressure for the wells to be drilled along the foot of the mountain or in the valley. A second source is from the streams that cross the upturned strata. In many instances we will find a good-sized brook in the granitic areas, but by the time the stream has passed oner a few hundred rods of sedimentary rocks, on edge or nearly so, the volume will be found greatly diminished and sometimes it entirely disappears. On account of these conditions the most favorable water-bearing zones will be found in the formations that extend highest up along the mountain slope, unless the rocks are faulted or so eroded as to allow the water to escape near the base of the mountain and prevent storage. There are also other considerations to be taken into account that pertain to the water zones. It is not simply water that is needed, but it must be sufficiently pure to be utilized for town, stock and irrigation. In order to meet these requirements it must not contain much mineral and be comparatively free from sulphur and entirely devoid of petroleum. All of these are associated with wells and springs in Wyoming. A well at Green River contains 24 per cent of sal soda; a spring near Beaver oil basin contains 10 per cent of sal soda; a well on Twin creek flows oil and sulphur water, and many wells at ranches all over the state have had to be abandoned on account of the salts of soda and magnesium. There are a few general rules that can be applied to the water-bearing rocks of Wyoming. The Paleozoic* rocks contain the purest water, and it is always good unless found in the regions where petroleum occurs, or occasionally contains a little common salt. The water is usually hard, since it contains considerable lime. The Paleozoic is also the most desirable since it will be found to furnish the largest flows. In the Mesozoic, waters usually carry large percentages of salts, especially sulphates of sodium, calcium and magnesium. Wells drilled at random in these rocks will as a rule contain inferior water and in many cases it will be found unfit for any use. The choicest bands in the Mesozoic are Triassic and the Dakota of the Cretaceous. The Triassic yields poor water for household purposes when the well receives a water supply from a gypsum bed, but it is in no way detrimental for irrigation. Occasionally a flow of salt water is encountered in the Dakota. Above the Dakota the chances to secure good water diminish, and anyone drilling in any of the Cretaceous rocks from the Benton up should consider that the chances to secure poor water are greater than those to secure good. Especially is this applicable to coal regions. There would not be sufficient evidence to warrant anyone in calling it a water-bearing zone. Below the mountain slopes the Triassic red sanstones and the Dakota sandstones usually have springs accompanying them.

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*Earlier rocks are not considered under this head.

The Cenozoic will not be considered under this head, since few if any artesian wells will be found in these rocks. So far as investigation has gone, the Tertiary waters are generally impregnated with sodium carbonate and sulphate, which has been found so plentiful as to render them useless for any purpose unless it be for the manufacture of soda.

The following table will give some information as to the general nature of water that may be found in the various geological horizons:

MIOCENE.—As a rule the water is very good. (In Dakota this formation yields very poor water).

OLIGOCENE.—Water contains soda salts and magnesium generally; but good water is found occasionally.

EOCENE.—Very inferior water, salts of soda being the most common; water often alkaline.

LARAMIE.—Water very poor, but often good for irrigation. Sulphur water common, also salts of soda, lime and magnesium. Occasionally good water in thick bands of sandstone.

FOX HILLS.—Both good and bad water, about equally divided.

FORT PIERRE.—Very poor water as a rule.

NIOBRARA.—Good water is found in the chalks; otherwise inferior.

FORT BENTON.—Usually inferior water.

DAKOTA.—Excellent water in the sandstones, usually quite soft. Sometimes brackish. In the oil fields usually sulfurous and otherwise disagreeable.

JURASSIC.—Usually very poor; a few bands of sandstone furnish fair water.

TRIASSIC.—Excellent water except in connection with the beds of gypsum.

PERMIAN AND CARBONIFEROUS.—Excellent hard water, except in the oil districts. Brackish water found at Rawlins.

DEVONIAN.—?

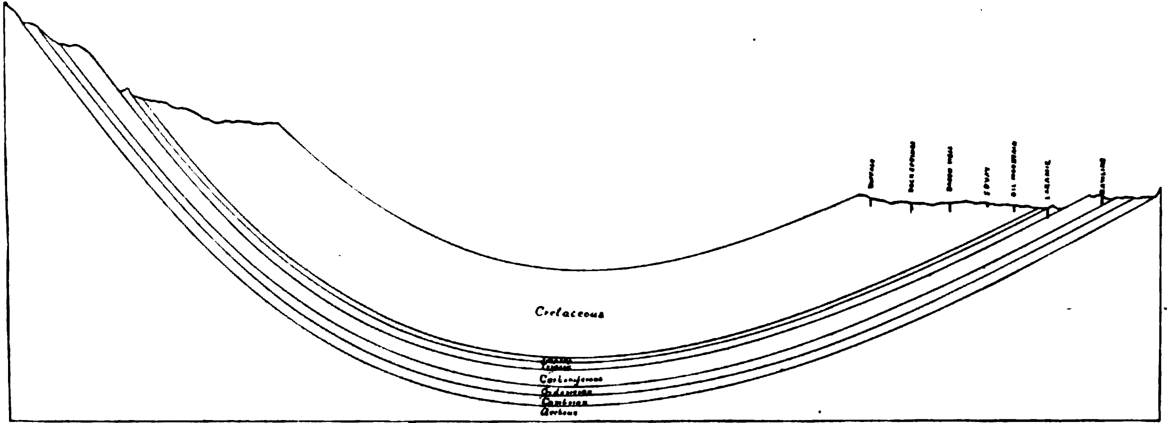
ORDOVICIAN.—Excellent hard water.

CAMBRIAN.—Excellent water. Near the base of the beds usually quite soft.

ALGONKIAN.—Very good water except in mineralized districts. Where the water comes from any great depth it contains various salts.

ARCHÆAN—The purest water found in the state except in mineralized districts.

SECTION I.



Section of an ideal artesian basin in Wyoming, showing the general type and geological position of some of the artesian wells.

Artesian Wells.

The name artesian, as applied to wells today, was derived from the name of French province Artois, where welis of this nature first became famous. In reality, the artesian well is not a modern discovery, for in the old Carthusian convent at Lillers there is a well that has flowed a constant stream since the twelfth century. There are other data which antedates this, and it is probable that flowing wells were known to the Chinese and Egyptians as early as the Christian era.

Originally the word artesian meant flowing wells only; but the meaning has been so broadened in the United States that it includes flowing wells, wells in which the water rises nearly to the surface, and also bore holes that contain water, it matters not how far it is from the surface. Wells that do not flow are not in reality artesian; but much less are those artesian where the water has to be elevated from 50 to 300 feet. The term as used in this bulletin will apply only to flowing wells. In justice to some who have used the word in a broader sense, it may be well to state that wells not flowing have been called negative artesian wells, and those flowing positive artesian wells. The word as used in this bulletin answers the scientific definition of an artesian well, as will be found in all physical geographies and geologies.

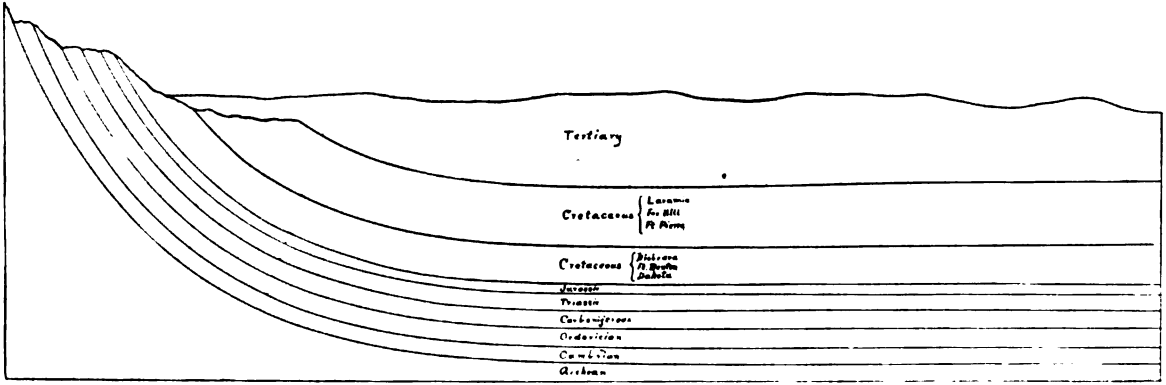
In order to secure an artesian well it is necessary that the strata dip and that they extend above the level of the mouth of the well sufficiently high to furnish a water storage and also hydrostatic pressure. Usually the stratum containing the water is quite porous and is confined between two impermeable strata. In nearly every artesian basin there are numerous water-bearing horizons, all of which may become tributary to a single flow; or they may be brought to the surface in individual pipes. It is not an uncommon thing to secure several kinds of water in drilling a deep well. One stratum may contain an unusual amount of gypsum or sulphuretted hydrogen, which would render it unfit for household use; but would in no way interfere with irrigation. Water of this kind could be brought to the surface in an independent pipe and utilized for irrigation purposes. It often happens that a good flow of hard water is found and just below it a flow of soft water. These can also be separated in the same way. During the last fifty years well drilling has improved in many ways, and especially in sinking deep wells and passing through very soft strata. A century ago a well 500 feet deep was a remarkable one; but at the present time there are wells that are over 6,000 feet deep.

In drilling deep wells a great deal depends upon the nature of the strata.

In Wyoming wells can usually be drilled in the Paleozoic rocks without the use of casing, unless it is put in to shut off a water flow. In the Mesozoic rocks the conditions are entirely different and a driller should be ready to handle a bad cave in any of the formations above the Triassic. In localities where no test wells have been drilled, it will always be advisable to start a large well, if drilling in the Mesozoic strata, so as to allow for casing the caves and to finish with a medium bit. Whenever it is possible, a careful geological section should be made of the strata through which the well is to be drilled. For in this way a driller can locate approximately the soft bands and be prepared to handle caves and also judge of the size of drill to start with to reach a certain zone. In making a section, one should examine the strata in which the well is to be drilled where they are found outcropping along the surface on a mountain slope or in a canyon. In taking measurements for thickness, make due allowance for dip.

It occasionally happens that after a flow has been obtained it suddenly disappears when the drill pierces a porous stratum which does not contain water. Occasionally this may happen when the well is practically finished or that the depth limit

SECTION II.



Section of the type of artesian basins along the eastern flank of the Laramie mountains.

has been reached. In a case of this kind, it is very important that the well be reclaimed if possible. The following suggestions may often prove to be of value. In case the well cannot be drilled deeper, and the flow of water was satisfactory before it was lost, it will be advisable to make a seed bag about the size of the well. The bag is made by sewing up a piece of leather—buckskin is excellent—making a sack that when filled with flaxseed will be about a foot in length. Be sure to make this sack so that when filled it will be small enough to be dropped by means of a rope to the bottom of the well without causing any trouble. Before lowering, have the bag tied, or better, sewed. As soon as the sack is in place it should be packed by lowering the "string of tools" with a cylindrical wooden block in place of a drill and this allowed to fall gently a few times. The flaxseed will swell immediately and in a short time the flow of water will be blocked and it will rise in the well. Several precautions are necessary to do this work successfully. The drill hole in the porous band should not be deeper than the seed bag is long; if deeper, it can be filled with sand or rock. In case a mistake is made with the first a second seed bag can be lowered. As soon as the bottom of the well has been blocked and the water commences to rise a second block can be put in. This should be of Portland cement. The cement should be mixed so that it will pass through a pipe easily. A pipe should be lowered nearly to the bottom of the well—say a foot from it. Then the water should be forced out of the tube by applying air under pressure until the bubbles rise in the well. Then the cement should be allowed to flow into the tube without permitting any air to enter, and the bottom of the well filled to the depth of a foot. This cement will soon harden and make a permanent blocking.

The seed bag will also be found useful in many instances when a flow of very poor water has been found below good water, and it has been found advisable to block the well, rather than attempt to pack with some of the usual packers now in use.

It often happens that a deep well has to be finished with a very small drill and that it is impossible to ream it out after completion. If the water-bearing zone is a solid sandstone or limestone it will be found advisable to shoot the well with dynamite or a little nitro-glycerine. By an explosion of this kind on the bottom of the well a greater surface will be opened up and the flow materially increased. There is one precaution necessary. If the water-bearing zone has been punctured with the drill, and the stratum below happens to be thin, there is a chance that the floor of the water-bearing zone would be fractured, and cause the water to enter a porous, non-water-bearing zone below and never rise to the surface again.

The cost of drilling wells will vary greatly. It has been customary for drillers to charge $2.00 per foot to drill shallow wells, while in the east the cost of drilling deep wells ranges from 40 cents to $2.00 per foot. Wells that can be drilled along lines of railroad in Wyoming should be drilled to a depth of 4,000 feet at a cost of not to exceed $2.00 per foot; understanding that this price does not include casing. When any of the basins in the state become known by drilling wells, the price of drilling will rapidly diminish, for the information obtained by one will in all cases be very beneficial to those who follow, and in the majority of cases the well will not only show the nature of the strata, but also the places where casing is necessary.

There is one danger that will possibly affect more or less the artesian wells in the future. Each basin has a certain capacity and the moment that the tax is greater than the supply all wells securing water from that particular zone in a community will be affected. In some artesian basins in the world the wells have increased in number, until finally none of them would flow at all. Such is the case in the basin near Denver The question of drilling the proper number of wells in any basin is one that should be considered; but there is no law that can in any way regulate it, since each land owner would have equal rights in a case of this kind. All will admit, no doubt, that a basin with 200 flowing wells that would irrigate considerable land would be far superior to 500 that would furnish only enough water for ranch use.

Up to this time, none of the ranchmen in Wyoming seem to have considered the advisability of drilling to secure artesian water for irrigation purposes. The question of water storage has been advocated for several years and a number of small reservoirs have been put in, and a few large ones are being constructed. Nature has already arranged an underground storage of water in many places in the state, and these should be considered before vast sums of money are spent in erecting dams to retain water during flood-tide. Irrigation by means of artesian wells is not a new nor untried scheme. It has met with success in numerous instances, especially in California.

Up to the present time very little attention has been paid to artesian well drilling in this state. There are, however, a few flowing wells, many of which were drilled for oil or in search of oil and gas. In the Laramie basin there are a dozen wells ranging from 100 to 1400 feet in depth, but the majority being less than 300 feet in depth. The wells near Laramie have all been drilled in Triassic sandstone and two or three have penetrated the Permian rocks below. While many of these furnish ample water for a large ranch, none of them could be considered as producing enough for irrigating a small tract of land. With depth, the flow of all of these wells could be greatly increased. For example, the greatest flow of water in the Laramie basin will be found at the base of the Carboniferous in a coarse grit or in contact with the granite. To reach this lower zone, the deep wells would have to be drilled from 600 to 800 feet deeper. The flow of water should be at least ten times what it is at present. At Rawlins conditions are similar. Here the wells are in the Carboniferous and the largest flow will be found in the Cambrian, probably near the granite. The Rawlins wells should be drilled to bed-rock to insure the greatest supply of water. At other places wells have been drilled, but they are usually quite shallow and flow slight streams of water. So long as wells furnish only small supplies of water there will not be any incentive to drill deeper ones. It must be remembered that it will be the deep wells that will furnish large flows, and without these we cannot expect the enthusiasm displayed that would be had a few wells been drilled that would produce a half million or more gallons per day. There is no question in my mind but that the future artesian wells of Wyoming will irrigate large tracts of land and in some instances the pressure will be found sufficient to apply the flow to a water wheel and furnish power to be utilized for any purpose. In South Dakota electric plants and mills are operated by power direct from the wells and the water afterwards utilized for irrigation.

The following table will give a list of the artesian wells that have been drilled in Wyoming, together with such other information that may be of interest:

Name of Well	County	Geological position	Depth	Flow in gallons per 24 hours	Kind of Water
S. W. Downey	Albany	Triassic.	2—1	3,927	Good
O D. Downey	"	"	170	8,640	"
S. W. Downey	Carbon	Fox Hills.	380	Small	Poor
Oxford Ranch	Albany	Permian	540	"	Good
Thomas McHugh	"	?	112	1,000	"
Thomas McHugh, No. 2	"	?	117	831	"
J. Simpson	"	Triassic.	112	864	"
G. Montague	"	"	150	Small	"
Ryan Bros.	"	"	85	840	"
Rawlins No 1	Carbon	Carboniferous	467	108,000	"
Rawlins No. 2	"	"	486	482,000	Good: brackish
Saratoga	"	Tertiary	55	72,000	Good
University	Albany	Permian	1015	50,000	"
County	"	"	1470	. . . . . .	"
Judson	"	Fox Hills	540	Small	Sulphur; poor
George	"	Triassic.	140	Quite large	Good

Name of Well	County	City, if any	Geological position	Depth	Flow per 24 hours	Kind of Water
. . . .	Johnson. .	Near Buffalo .	Laramie .	2—1	Small. .	Good
Guthery . . .	Natrona. .	. . . .	Dakota . .	1000	" . .	Sulphur; poor
Rock Springs	Sweetwater	Rock Springs .	Laramie .	. . .	" . .	Poor
. . . .	Natrona. .	Near Frvay . .	Niobrara .	. . .	" . .	"
Bacon	Albany. .	. . . .	Fox Hills .	. . .	Medium	Good
Mullen . . .	Fremont .	Dallas	Permian ?.	1200	"	Oil; sulphur water

INSTRUCTIONS FOR LOCATING ARTÉSIAN WELLS.

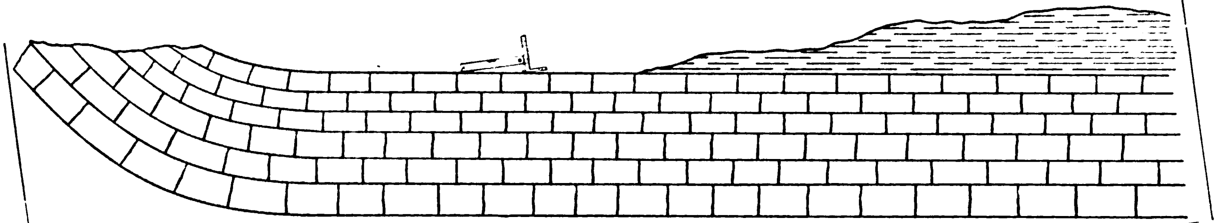
It is not an easy task to locate with assurance an artesian well in a new basin. The many factors entering into work of this kind are so variable that a person may reasonably hesitate in forming an opinion or rendering judgment. Unfortunately it has been the rule to drill regardless of any scientific data that may be at hand. When once an artesian basin has been punctured with a drill and an accurate log kept of the work, those that follow have a comparatively easy task. In advice of this nature it is utterly impossible to make rules that will apply to all cases. It is also impossible to give the necessary information as to the depth of wells and the quantity of water one might reasonably expect.

The location, the geological formation, and the depth of the well all have an important bearing on this subject. A well in one basin 2,000 feet deep might furnish 1,000,000 gallons of water a day, while in another the flow might only be sufficient for one ranch house. Before anyone attempts drilling a well in any of the basins, unless he is fortunate enough to have ample funds to experiment with, let him consider the following essentials:

1. Be sure that you are in an artesian basin and that there are strata above you of sufficient magnitude to warrant a storage of water.

2. Examine the nature of the strata and determine if

SECTION III.



An illustration showing how the dip may be taken with an ordinary level and square.

possible the geological horizon, that you may compare your locality with others, where wells have been drilled. If this cannot be done examine the lithological characters of the strata and satisfy yourself whether they are porous or impermeable and note if at any point you can find springs which would signify an overflow of the basin.

3. Before drilling estimate the thickness of the formations that you will have to drill through and the difference in elevation between the point where the rocks were exposed and the selected place for the well. In order to do this, estimate the dip of the rocks, and use also the thickness in the estimate.

METHOD OF TAKING DIP.

Use a clinometer to measure the dip with, but in case you do not possess one use an ordinary carpenter's level. Select some place along a gulch or canyon where the strata have been worn into a vertical wall and examine carefully until you find the strata dipping toward the site of the well location. At this point place one end of the level on the highest side of a bedding plane and adjust the instrument until it is perfectly level. While being held in this position have an assistant measure accurately the distance from the elevated end of the level downward to the bedding plane. In this way you have data that gives you the dip of the rocks in terms of inches per foot which can easily be converted into feet per mile. Several readings should be taken in an estimate and these averaged. In case the clinometer is used it will be necessary to use trigonometrical formulae to ascertain the number of feet the strata dip per mile. In either case it will be necessary to measure the distance from the point where the dip was taken in a horizontal direction to the well location. This measurement multiplied by the dip in feet or inches per mile will give approximately the depth to drill to reach a certain horizon. From this depth should be subtracted the difference in elevation between the point on the hill where the estimate for dip and thickness were made, and the well.

A Table Giving the Vertical Depths from the Surface for Each One Hundred Feet Measured Horizontally, for all Degrees of Dip Between 1 and 90.

In using this table, multiply the number of feet you have measured horizontally, by the number of feet placed after the degree of the dip you are working with. For example: if the dip of the formation is 12 degrees, and you wish to find out how deep you would have to drill at a point 4,200 feet away, you would have to multiply the 42, which represents the number of hundreds of feet, by 21.25 feet.

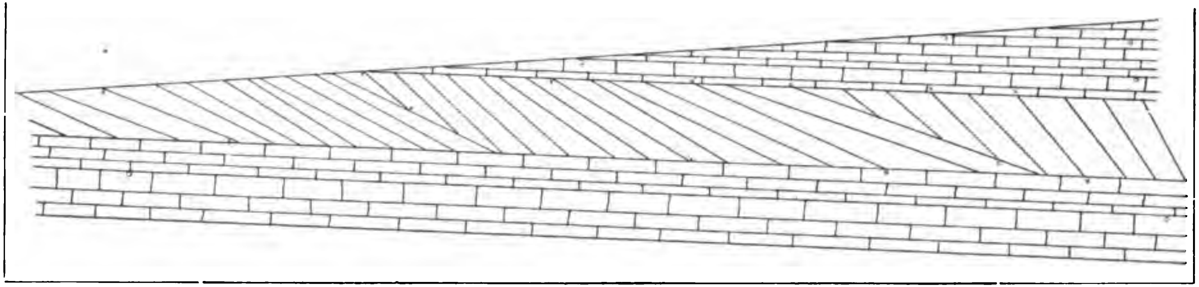
The estimate, made in this way, would be considered as horizontal from the outcropping strata, and from this should be subtracted the difference in elevation.

Degrees of dip	Vertical depth for each 100 feet measured horizontally	Degrees of dip	Vertical depth for each 100 feet measured horizontally
1 degree.......	1.75 feet	18 degrees......	32.35 feet
2 degrees......	3.50 feet	19 "	34.50 "
3 "	5.25 "	20 "	36.50 "
4 "	7.00 "	21 "	38.50 "
5 "	8.75 "	22 "	40.00 "
6 "	10.50 "	23 "	42.25 "
7 "	12.50 "	24 "	44.50 "
8 "	14.00 "	25 "	46.75 "
9 "	16.00 "	26 "	47.75 "
10 "	17.50 "	27 "	51.00 "
11 "	19.50 "	28 "	53.25 "
12 "	21.25 "	29 "	55.50 "
13 "	23.25 "	30 "	58.00 "
14 "	25.00 "	31 "	60.25 "
15 "	26.75 "	32 "	62.50 "
16 "	28.50 "	33 "	65.00 "
17 "	30.00 "	34 "	67.50 "

Degrees of dip	Vertical depth for each 100 feet measured horizontally	Degrees of dip	Vertical depth for each 100 feet measured horizontally
35 degrees	70.00 feet	63 degrees	200.00 feet
36 "	72.50 "	64 "	205.00 "
37 "	75.25 "	65 "	213.00 "
38 "	78.00 "	66 "	224.00 "
39 "	81.25 "	67 "	235.00 "
40 "	84.00 "	68 "	250.00 "
41 "	87.00 "	69 "	260.00 "
42 "	90.00 "	70 "	275.00 "
43 "	93.00 "	71 "	300.00 "
44 "	96.00 "	72 "	308.00 "
45 "	100.00 "	73 "	327.00 "
46 "	104.00 "	74 "	345.00 "
47 "	107.00 "	75 "	370.00 "
48 "	111.00 "	76 "	400.00 "
49 "	115.00 "	77 "	433.00 "
50 "	119.00 "	78 "	476.00 "
51 "	123.00 "	79 "	515.00 "
52 "	128.00 "	80 "	570.00 "
53 "	133.00 "	81 "	633.00 "
54 "	137.00 "	82 "	714.00 "
55 "	143.00 "	83 "	813.00 "
56 "	150.00 "	84 "	1000.00 "
57 "	154.00 "	85 "	1140.00 "
58 "	161.00 "	86 "	1430.00 "
59 "	166.00 "	87 "	1912.00 "
60 "	172.50 "	88 "	2865.00 "
61 "	180.00 "	89 "	5714.00 "
62 "	188.00 "	90 "	——

In measuring dip greatest care should govern the work and average dip planes considered. In some instances the strata rise and fall in a wave-like structure, which makes an estimate for depth quite uncertain. Special caution should be taken at all times in taking dip, owing to cross-bedding structure of many sandstones, and especially the Triassic. By

SECTION IV.



Ideal illustration of cross-bedding planes. The oblique lines terminating at the letters x are the cross-bedding planes and the less oblique lines marked o are the natural bedding planes.

cross-bedding it is meant that there are appearent bedding planes not conforming to the dip of the strata.

For estimating differences in elevation an aneroid barometer will be found useful; but you must make an allowance for at least twenty-five feet in reading an ordinary instrument. In a case of this kind the reading should be taken at either the top or bottom of the slope and the second one follow as soon as possible, in order to avoid the error that may be caused by a change in the atmospheric pressure. The difference between the two readings gives the approximate difference in elevation.

In case you cannot secure an aneroid barometer, use the same method as recommended for determining the dip of the rocks. Select a place if possible where you can sight from the exposed stratum down to the well location. Arrange a piece of 2x4 on this line, which will represent the average slope of the mountain or hill, and then apply the level and square, which will give you the inches fall per foot, and knowing your horizontal distance you can easily estimate the elevation. It will often happen that one cannot sight the entire distance. Then it will be necessary to take several readings and also horizontal measurements and add the results for entire elevation.

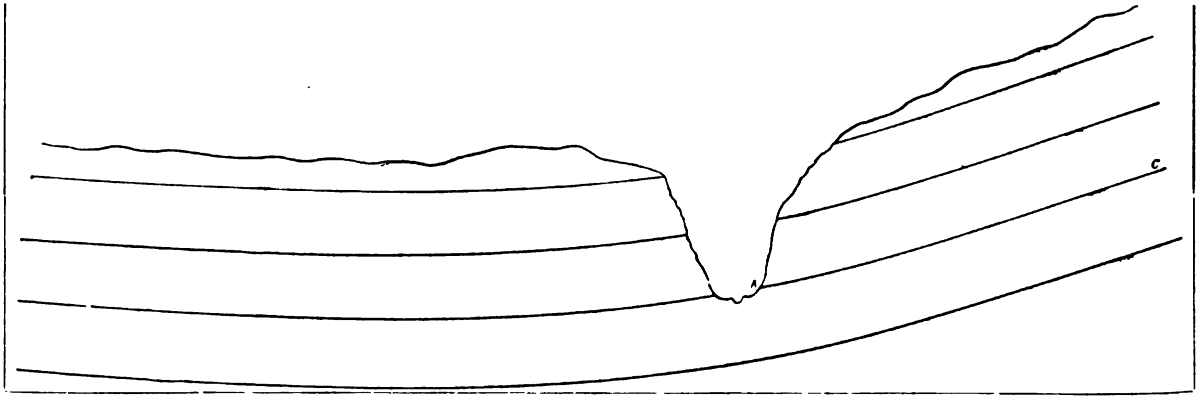
In case a location is being made along a mountain slope be sure that you are not working in a drained area. Such often occur in good basins.

EXAMPLE.

It would be useless to drill for water at any point between A. and C., since the canon that has been cut through the rocks has provided natural drainage for all the strata above the letter A. See Section V.

It will often happen that wells are needed in regions where all of the formations or nearly all are covered with soil, which will almost forbid any preliminary work. However, in case the well is to be drilled in any of the artesian ba-

SECTION V.



An illustration showing how an area in an artesian basin may be entirely drained by a canon paralleling the strike of the formation. Illustration taken from Canon creek, Big Horn county.

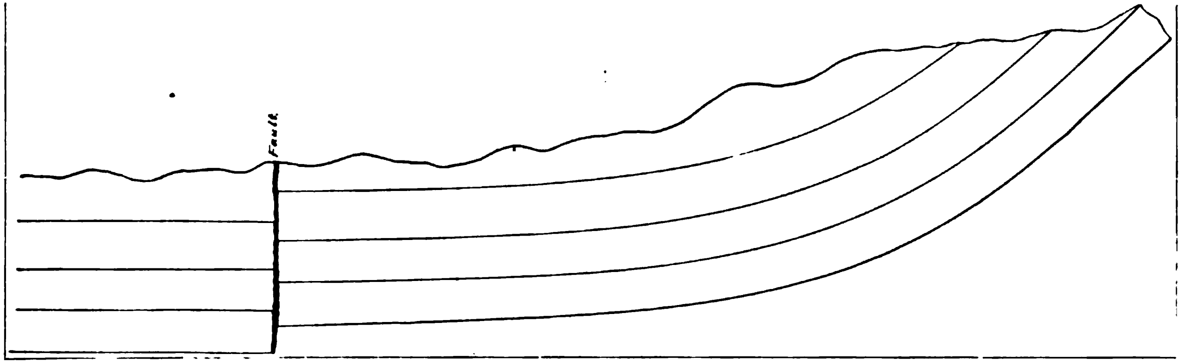
sins, and not too far from the mountains, a flow of water can easily be secured; but the amount depends upon the natural reservoir above, and the nature of the formation in which the well is drilled.

In drilling wells there is bút a single point to consider. Hire a first-class man with a first-class drilling outfit. If possible secure a driller who is familiar with the formations. The differences in drilling in the Paleozoic rocks and the Mesozoic are so great that a man will be very successful in the first and fail in the second. The trouble is in the nature of the strata. In the Paleozoic a well can usually be drilled through the formations without being cased. In the Mesozoic the strata are in many places bands of solft clay, marl, and shales that cave easily, and it has in some instances been found necessary to start with a well 18 inches in diameter in order to finish with a three ane one-half inch drill, the difference in size being taken up with casing to hold caving ground.

The question might be naturally asked—why have not working directions been given for each locality? It would have been well to have enlarged upon this topic if there was an accurate geological map of the state, so that one would know from the map the exact formations to be found in each township in Wyoming. As it is, the map that accompanies this bulletin has been made from reconnaissance surveys only, and while the structure is nearly accurate the boundary lines between the formations may vary several miles and in some localities the map will be found to be seriously at fault. For these reasons no detailed directions for any section of land in a region will be attempted. However, at all times the geological department of the University will be pleased to aid in the location of wells and so far as possible make examinations and give directions for drilling artesian wells in any locality in the state.

In some localities where the strata dip sharper than 45

SECTION VI.



An illustration showing how an artesian basin may be partially drained by a fault. Example taken from the Laramie artesian basin.

degrees it will be found to be advantageous to drive a tunnel into the mountain that will cut the sedimentary rocks at right angle to the strike. Tunnels of this kind are not very expensive and they are by far superior to a well. They open a greater area of the water-bearing strata, and by driving drifts at right angle to the main tunnel an immense amount of ground could be opened. Cross-cut tunnels of this kind in mining camps often give rise to a small river.

The Artesian Basins.

THE BIG HORN ARTESIAN BASIN.*

In many respects this is the most promising artesian area in Wyoming; but in this, as in all sections, the most valuable part is covered so deep with sedimentary rocks as to render it unavailable. Being located between two great ranges of mountains, like the Big Horn on the east and the Absaroka and Shoshone on the west, whose highest peaks are above the line of perpetual snow, and whose forest areas are so vast as to store great snow reserves that supply water gradually to these ranges, the water supply is very great. On the south this basin is hemmed in by two cross ranges which meet at the Big Horn river, the western portion being called the Owl Creek range and the eastern, which extends to the Big Horn, is locally known as the Rattlesnake. To the northward this area melts away into the great table lands along the Missouri river in Montana. The formations entering into the structure of these basins are as follows: Cambrian, Ordovician, Devonian, Carboniferous, Permian, all of the Wyoming Mesozoic bands and the Eocene Tertiary. These formations, with the exception of the Eocene, dip gently to the west along the western slope of the Big Horn range and are found resting upon the Archæan at elevations varying from 7,000 to 9,000 feet. As a rule, all of the Mesozoic rocks have been removed from the mountain slopes and are not usually seen until the foot of the mountain is reached, when the Triassic red sandstone usually appears as huge "hog-backs" with precipitous walls facing the range. North of Hyattville some miles the rocks dip at a higher angle and for a considerable distance the Mesozoic rocks are found within a few miles of the Archæan granite. These conditions again change on nearing the Montana line, where the Paleozoic rocks dip gently as they bend about the north end of the Big Horn mountains and form many square miles of exposure corresponding to the southern end of the western slope of the range.

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*That portion of the Big Horn basin lying north of the Stinkingwater river that has been represented on the map as Tertiary, belongs to the Fort Union beds. No Wasatch was observed north of the Stinkingwater river.

In the vicinity of Hyattville there are three local folds. In the one west of Bonanza the exposure is entirely Cretaceous. The one between Bonanza and Hyattville has a Jurassic core and possibly Triassic rocks may be exposed along the axis further to the north. At Hyattville the fold has been nearly obliterated by erosion. All of these folds weaken the head of water stored in the Mesozoic rocks above the Triassic.

Between Hyattville and Red Bank there are numerous springs breaking forth from Carboniferous and Permian limestones, indicating faults, and along Canon creek large areas of Paleozoic rocks have been drained by the deep canons which are parallel to the axis of the Big Horn range in the limestone. North of Shell creek, and extending northwest across the Big Horn river, are two other anticlinal folds, the greater of which has a Carboniferous core and the lesser a Triassic. While these folds have seriously affected the basin along the foot of the Big Horn mountains, they may also be considered as advantageous; for if they are complete arches, that is, not fractured or faulted, they are favorable places to drill and secure flowing wells a considerable distance away from the range. For example, southwest of Bonanza, in the Bonanza oil field, exceptionally large flows may be secured by drilling 2,000 or 3,000 feet. At Hyattville one would not have to drill over 200 feet to reach the same zone in the Triassic sandstone.

Along the eastern side of the Big Horn basin the most desirable territory for well drilling will be found from the crest of the Triassic sandstones toward the mountains. In case wells are drilled in the Triassic, one should drill not less than 2,000 feet. In case shallower wells are desired it will be better to drill in either Carboniferous or Ordovician strata.

Beyond these disturbances, to the westward, the Mesozoic rocks appear, and especially the Cretaceous, which is capped with the Laramie. Westward from the Laramie the Eocene Tertiary covers the entire central area of the basin and extends nearly to the foothills to the west.

On the western edge of the basin the structural features are not so easily worked out. Following the period of mountain making, after the sedimentary rocks had been tilted and eroded, there was a vast accumulation of volcanic breccia deposited for a distance of sixty or eighty miles along the mountains. This has greatly obscured the geology of this region and also hinders materially in the search for artesian water. This great deposit has a width of from ten to forty miles and a maximum thickness of 5,000 or 6,000 feet. Between this deposit and the Tertiary on the east there are exposures of the upper Cretaceous series; but none of the older rocks are known from the Owl Creek range northward until the Stinkingwater river is reached, where there are slight exposures of Paleozoic rocks which extend northward to the Archæan mass on Clark's fork.

In the vicinity of Cedar mountain conditions are quite complicated. This mountain is an anticlinal fold, with probably a Cambrian core, and with the strata highly inclined on either side. To the westward there is a broad synclinal valley that will undoubtedly prove to be valuable artesian territory. On the eastward the strata, although sharply inclined along the mountain, flatten very rapidly toward Cody, which makes the area along the base of Cedar mountain a very fair artesian proposition. Northward, above Chapman's ranch, the opportunities for wells are excellent, but from Clark's fork north to the Montana line the Paleozoic rocks are nearly vertical and the productive area is very narrow unless wells are drilled in the Mesozoic. Along the range from Cody north flowing wells will be found in all of the Mesozoic rock. West of Clark, tunnels may prove to be useful in securing water from the nearly vertical strata.

The structure of the southern end of this basin resembles, to a considerable degree, the eastern border, except that the mountains are not so high. The width of the basin at the southern termination is nearly eighty miles, and artesian conditions extend the entire distance. Along the Owl Creek mountains, including the uplift on the east side of the Big Horn river, the Archæan, so far as known, is only exposed along a portion of the distance. For many miles along the axis of these ranges the Carboniferous or Carboniferous and Permian rocks, form a complete arch that has not been fractured. On this account the extreme eastern and western sides along this border are not as favorable for valuable wells as the central section. The strata dip gently northward from the Archæan rocks along the northern side of the range, and there is an area composed of Cambrian, Ordovician, Carboniferous and Triassic stretching across the end of the basin that varies from ten to twenty miles in width. At no point in this area will it be necessary to drill more than 3,000 feet to reach bedrock, and over the greater portion not over 1,500 feet. The Big Horn river has to some extent drained the strata that lie above the river bed. Near Thermopolis, at the great hot springs, the water rises in numerous places, proving conclusively that there is a very good fountain head. The warm water pouring forth from these springs derives its heat by sinking deep into the earth and coming in contact with heated rocks and being forced to the surface through a fault by means of the pressure derived from the storage of water along the mountains. In this, as in other parts of the basin, artesian wells can be drilled further away from the range, and no doubt they will flow; but the supply of water would be quite limited unless a well could be drilled to five or six thousand feet.

Throughout the central portion of the basin no one will be warranted in drilling wells expecting to secure artesian water. The Eocene formation is usually quite thick and on account of its sandy and clayey texture would foil the most expert well driller before he had reached 1,000 feet.

The most valuable portion of the entire basin extends from Red Bank north to Shell creek; valuable because wells can be drilled to reasonable depths and secure an abundance of very good water.

See Section VII for geological structure of Big Horn artesian basin.

THE SHOSHONE ARTESIAN BASIN.

The basin is bounded on the north by the Owl Creek and Big Horn mountains; on the east by the Powder River basin; on the south by the Rattlesnake range and the high bluff of Tertiary extending from the Rattlesnake westward to Beaver creek and the Wind River mountains; on the west by the converging Wind River and Owl Creek ranges. As the limits are given, this basin emerges into the Powder River on the east, and at several intervals along the southern border there are no barriers that would prevent it from extending further southward. The remaining exteriors are, however, valuable territory and will be discussed under separate headings.

The northern border skirts the Owl Creek and the western extension of the Big Horn mountains. This range is continuous and has different names on opposite sides of the Big Horn river, which cuts it in two. These slopes have not been studied and the present observations are based on information secured in crossing these ranges. In the main uplift in the vicinity of the Big Horn river there is a narrow Archæan mass that extends from east to west to an unknown distance, and as plotted on the map is largely guess-work, Mr. J. B. Okie of Lost Cabin having informed me that there was granite north of his place and that it extends westward to the known mass at the Big Horn seems reasonable. The forces producing this great fold that hems in the Big Horn basin on the south operated from the north and caused the sedimentary rocks to dip sharply to the south. This dip gradually decreases to the eastward and westward, to the respective boundaries. South of the Archæan uplift the exposed formations are Cambrian, Ordovician, Carboniferous and Permian(?); south of this all of the Mesozoic rocks are covered with Tertiary. Eastward the Triassic sandstones appear at a distance and will more than likely be found along this uplift. The supply of water will not be large, since this region is wholly dependent upon the precipitation for storage unless it may be possible for some of the porous strata from the Wind River range to augment this supply.

The crest of the Owl Creek range west of the Big Horn river a few miles, with the exception of a few small exposures of Archæan, is all Carboniferous or Permian. Similar conditions exist in the lower Big Horn range east of Lost Cabin. This arch of limestone is very detrimental to the storage of water in the Paleozoic, and unless it is fractured in numerous places, wells drilled to this horizon either eastward or westward from a line extending southward from the termination of the Archæan will be found to be unsatisfactory. Opposite the Archæan, to the south, the Paleozoic rocks are so highly inclined as to make the productive area very narrow, and deep wells will be necessary to reach a flow. About Lost Cabin the Triassic red sandstone seems the most desirable band to penetrate with a drill, though possibly the upper band of the Carboniferous will be found equally valuable. The same can

be said of the western end of the flank of the Owl Creek mountains. Cretaceous strata, whenever exposed, will be found to contain many water horizons, and the best may be expected in the Dakota stage.

Wells may be drilled along the base of this range when there is a thin covering of Tertiary, but a few miles away would carry one beyond the bounds of reasonable well drilling.

There is no question but that there is quite a large basin along the foot of this range for ten or twelve miles, and beyond this the Jurassic rocks appear. Probably there are some Cretaceous exposures along the streams flowing south and west, where the Tertiary capping has been removed. Westward from the river the entire complement of the Mesozoic appears rather suddenly, since it occupies an elevation above the level of the Tertiary.

Since the western boundary of this basin is formed by the convergence of the Wind River and Owl Creek ranges, it will be discussed in connection with the northern and southern boundaries.

The Shoshone anticlinal parallels the Wind River mountains from Hailey nearly to the Big Wind river, a distance of over 50 miles. This fold is some distance from the range, the nearest point being five or six miles from the foot and double that distance from the Archæan rocks. The Triassic strata are exposed nearly the entire length along the axis of this fold. On the northeast the Jurassic and Cretaceous rocks dip away gently and only a few miles distant obtain considerable thickness. On the southwest side of the fold the Jurassic and Cretaceous rocks have suffered greatly from erosion and are seldom seen above the soil surface. This condition produces a long, narrow synclinal basin that lies between the anticlinal fold and the mountains. This can be considered as a small artesian basin. It is to some extent separated from the great basin along the northeast side of the anticlinal. This narrow basin, which gradually widens to the northwest, should be seriously considered by the people who live along this range, as sometimes there is a shortage of water. The possibilities are unsurpassed for large capacity wells, and the Mesozoic rocks are so thin near the range and often in the valleys that wells need not be drilled to great depths. The reasons for this being a specially favorable location are that Paleozoic rocks rise along the flank of the mountains two and three thousand feet above the valley and that the Archæan peaks rise far above the snow line and furnish a constant supply of water during the summer. Above Lander, on the forks of the Popo Agie river, there are places where it will be advisable to tunnel for water. When a tunnel has been completed from the base of the mountain to granite it will be found the bed of a good-sized stream. Excellent places to drill for water are along Red canon, at the experiment farm, and to the north and west along the outcropping Triassic rocks. At Lander and Fort Washakie wells could be obtained, but the depth would be very great. In cases of this kind it would be more advantageous to drill nearer the range and pipe the water to lower horizons.

Along the anticlinal axis wells may also be obtained. Already there is an artesian well near the mouth of Twin creek. This well was drilled to a depth of 1,200 feet. The formations lying beneath the axis of the fold are the Permian, Carboniferous, Ordovician and Cambrian, all of which are supplied with water from the range, and if not exhausted at this point will furnish a supply of water for the country lying beyond the fold to the northeastward. Well drilling to the northeast of the Shoshone anticlinal will have to be confined to a very narrow belt on account of the rapid thickening of the Cretaceous rocks. Beyond these limits no one should drill for the Paleozoic rocks. Wells may be drilled in the Cretaceous strata, but no one should expect more than a slight flow. Those who drill along the anticlinal must always consider that water found will usually be contaminated with oil and sulphur. While it may be possible to utilize such water for irrigation purposes, it would first be necessary to contrive a method to store the oil and allow the water to escape.

From the fold eastward the first distributed rocks are found at the Beaver oil basin, where the Cretaceous rocks stand nearly on edge and there are no associated Paleozoic rocks, since Tertiary has obscured them. Artesian wells can be secured, but the flow will be slight and the water unfit for irrigation, stock or ranch use on account of its contamination with sulphur, oil and alkali.

Eastward from the Beaver basin some five or six miles is the Connant anticlinal, which has a Carboniferous core and the Triassic and Jurassic rocks on either flank. About the base of this uplift the lower beds of the Cretaceous are exposed and wells drilled along these outcroppings will furnish a small supply of water which is very desirable in this very arid region. Here, as at Beaver, one should be prepared to encounter water containing sulphur or petroleum. Petroleum has not been found in this vicinity, but it does occur on both sides, and those drilling must choose well their location, for oil springs are numerous all along the ranges, and wells associated with petroleum would not furnish good water; the oil not being the only drawback, but the presence of an abundance of sodium sulphate being even more serious. Petroleum along the range is wholly confined to the Cretaceous rocks, but ranges from the Dakota to the Fox Hills.

From the Connant anticlinal eastward there is a nearly continuous precipitous wall of Miocene Tertiary that rises several hundred feet from the desert country and practically connects this section with the Rattlesnake mountains. Along the foot of this huge bluff are numerous small springs which have their source in the Tertiary rocks, but there are no conditions warranting well drilling.

Within eight or ten miles of the Rattlesnake mountains there is simply the termination of the Dutton anticinal, known as the Dutton oil basin. In this V shaped area the Triassic rocks are the oldest exposed, and the tilted bands along the anticlinals are so low that there is little or no opportunity for water storage. Along both sides of the fold there are a few small springs, some of which contain very poor water; others are associated with natural gas escapes and a few with petroleum. The conditions in this section are anything but favorable for a large supply of water, and yet I know of no region where water would be of greater benefit.

The Rattlesnake mountains form a peculiar range that is some 40 or 50 miles long and have probably been elevated by a huge fault that extended along the southwestern base. It is not definitely known that there are Archæan* rocks along the southern slope, but there is a complete series of rocks as known in central Wyoming, commencing with the Cambrian and terminating with the Tertiary, along the northern slopes. These rocks dip from 28 to 35 degrees and form great ridges paralleling the range which are occasionally cut by small streams. This range is one of the celebrated oil districts of the state and wells drilled in any of the Cretaceous bands may furnish water that is charged with sodium sulphate, sulfuretted hydrogen, and tainted with oil, since the petroleum ranges from the base of the Dakota stage to the crest of the Fox Hills.

On account of this drawback wells should be commenced in the Triassic and the flow looked for in the lower Triassic or Permian, and possibly in older bands. Along the range from Garfield peak eastward and westward for a distance of from 6 to 10 miles tunneling may be resorted to. Although this range is not high, there is every evidence that wells drilled or tunnels run will afford considerable water. This basin has already been proven, by companies drilling for oil, and at present there are one or two wells flowing very poor water.

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*Only recently, while investigating the Rattlesnake mountains, I found that the Archæan was exposed, and that it is chiefly a hornblende granite.

Eastward from the Rattlesnake range there is a broad synclinal valley partially covered with Tertiary rocks, and just beyond the Oil mountain fold. This fold has a Jurassic axis and is badly faulted and can not be considered as an important source for artesian water. Again, the presence of oil impairs its value. On Poison Spider creek, only a mile or two north of Oil mountain, the Guthery oil well has flowed a small stream of sulphurous water for many years. In regions like this, where water is very scarce, small wells like the Guthery may be found advantageous. Other wells drilled to greater depths but further away have not flowed.

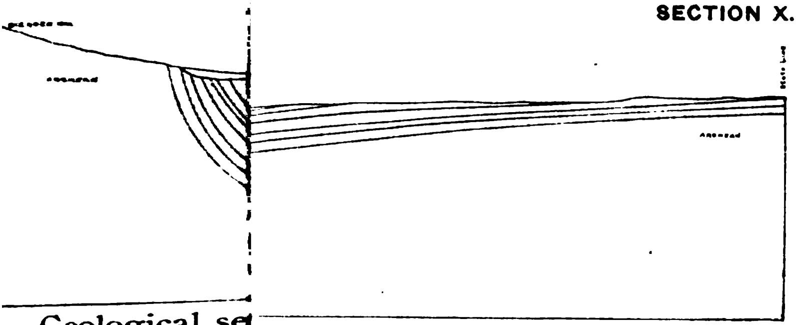
See Sections VIII and IX for geological structure of Shoshone artesian basin.

THE POWDER RIVER ARTESIAN BASIN.

This basin includes all of Sheridan, Johnson, Crook, and Weston counties; also the greater portion of Natrona and Converse. In reality it includes nearly one-fourth of the state. On account of some local geological disturbances this, the largest area to be discussed, might have been separated into several small ones; but since the lesser divisions would not be considered as important basins, it has been deemed advisable to include them under one head and pay special attention to the isolated districts. The western limit of this basin is the Big Horn range, with the exception of the depressed area lying between the Big Horn mountains and Oil mountain, where the boundary is the range line between ranges 82 and 83. On the south the Laramie mountains act as a barrier from the big bend of the North Platte river eastward to a point south of Douglas, from whence the line extends eastward to the stae line, over an area that does not offer any artesian nish large flows of water. Beyond the Triassic sandstones artesian flows can be secured almost any place in the valley lands or along the table lands; but the source of the water is in the Cretaceous rocks, and with the exception of the Dakota sandstone the chances are that very inferior water will be obtained. For example, a well a thousand feet deep at Sheridan would in all probability flow; but the water coming from rocks associated with coal is never good. Occasionally water in a coal formation, where there is a heavy band of sandstone between two bands of clay, is excellent. Wells drilled at Sheridan should not be expected to produce much water, since the strata that carry the water beneath the city crop to the surface between Sheridan and the mountains, and in consequence have a very limited water supply. Were it possible to drill deep enough at Sheridan, say 10,000 or 15,000 feet, the supply of water thus obtained would surprise the world.

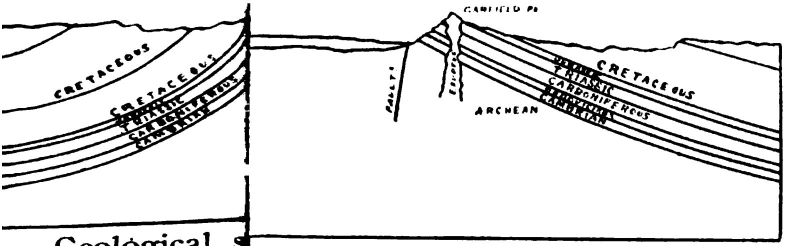
From Piney creek southeast and south the dip of the strata increases very rapidly until at a point opposite Buffalo they are nearly vertical; but southward they again decrease in inclination and at Crazy Woman creek the dip is only 15 or 20 degrees. West of Buffalo nearly all of the sedimentary rocks have been obscured by the detritus from the mountains, which along Clear creek is a very thick band of conglomerate. On account of the strata being nearly in a vertical position it will be impossible for anyone with modern appliances to drill and pierce any of the Paleozoic bands, and it is questionable if any of the lower Mesozoic rocks could be reached. South of Buffalo, as the dip decreases the opportunities for wells increase, and only ten of twelve miles south of Clear creek the territory in which the best wells can be secured has increased sufficiently to warrant large expenditures in drilling. Buffalo is located on the Laramie beds, which dip very slightly to the east. These beds will be found to furnish artesian water, but there will be the same drawbacks to consider as at Sheridan.

SECTION X.



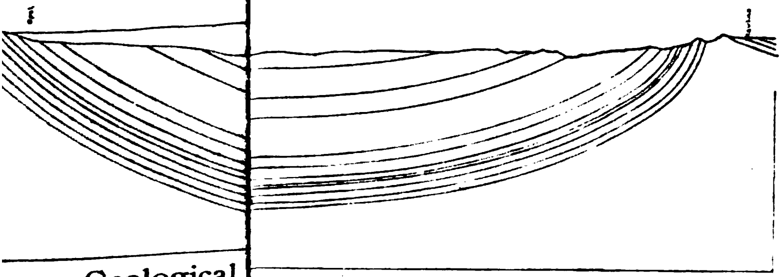
Geological se ine, across the Powder River artesian basin.

SECTION XII.



Geological s ntains. [Drawn to Scale.]

SECTION XI.



Geological across the Green River artesian basin.

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Already shallow wells have been drilled at Buffalo that produce small streams of very good water. Deeper wells will furnish more, but the chances are that the water would contain too much mineral matter to be used for domestic purposes or irrigation. From Muddy creek, south of Buffalo, to the southern termination of the Big Horn range, the strata gradually decrease in dip, which widens the Paleozoic outcrops along the range. Along the Big Horn mountains, nearly opposite Mayoworth postoffice, the Archæan rocks no longer appear on the surface, but are covered with a great arch of the Paleozoic, and the Carboniferous rocks form the crest of the range southward to the great bend in the range, and from thence westward. Along the mountain slopes the Triassic rocks are occasionally seen, but as a rule they outcrop at the foot of the range. In this portion of the range conditions are the same as cited in the southern end of the Big Horn basin, which is just across the mountains. Because the granite is covered with Cambrian, Ordovician and Carboniferous bands the storage has been greatly decreased. In case these rocks have been faulted or fractured the water supply would correspond favorably to that portion of the range at Muddy creek. On the other hand, the Triassic sandstone would be the leading horizon and the Dakota sandstone a second one below, but in neither place would the supply be large.

Along the southern boundary of the Powder river basin the Laramie mountains act as a barrier and along these the strata are tilted to the north at various angles depending upon the locality. Here the formations change. The Paleozoic rocks are very much thinner, the Ordovician series have not been detected, and the Cambrian, which has been found along the western arm of the Laramie mountains, thins very rapidly to the eastward. The remaining bands are the same as seen at Buffalo or Sheridan. The Laramie range practically terminates before reaching the North Platte river, which has cut its way across the northern extension through Triassic sandstone. In this vicinity there is a large spring in the Triassic sandstone that acts as an overflow for this section. Eastward along the range the Paleozoic rocks gradually decrease in dip, for many miles. There are in all probability some changes in geological structure along this range that have not been discovered. Between Douglas and Laramie peak there is a small secondary fold with a Triassic core, but with this exception nothing is known out of the regular anticlinal structure. The range is quite low, Laramie peak being only 10,000 feet and the rest of the granite peaks to the westward varying between 8,000 and 9,000 feet. Owing to the precipitous slope along the range opposite Casper, the Paleozoic rocks offer only a very narrow band in which to drill. South of Glenrock the conditions are more favorable, and opposite Douglas the productive area has so increased in width that the artesian possibilities are very promising.

Wells can also be secured by drilling in Mesozoic rocks, but the chance to secure large flows of water decrease very rapidly as one leaves the foot of the mountains. Flows may be secured at Casper, Glenrock and Douglas, but wells are not recommended for these cities: First, since the flow would not be important, and secondly, because the source of the water would probably render it too impure for ordinary uses.

The southeastern corner of the Powder River basin cannot be considered as of importance for artesian well drilling, not that the basin does not exist, but that it is by far too deep to drill and reach the valuable zones. Wells can no doubt be found eastward from Douglas, but the water will seldom if ever rise to the surface. This is largely due to the Tertiary beds of the Miocene period which cover this section and are in nearly horizontal strata. These strata vary from 1,000 to 1,500 feet in thickness. This thickness would have to be drilled through before the Mesozoic rocks that flank the Laramie range on the eastern slopes could be reached. North of Lusk and along the slopes of the Cheyenne river there is a small area of Fort Pierre shales and in this section wells may be drilled deep enough to reach the Dakota sandstone, which would furnish an ample water supply. Further to the northward the Laramie rocks appear and there is little opportunity to drill wells. At Newcastle and northward to Cambria and thence north and northwest, the country favors well drilling and a reasonable water supply may be looked for. This brings us to the region affected by the Black Hills uplift and some lesser folds. While the Black Hills are usually known as belonging to South Dakota, the Wyoming-Dakota line passes over some very prominent peaks of Algonkian schists, in the tin-bearing regions, which leaves a small area in Wyoming. On the western slopes of the Black Hills the Cambrian strata dip very gently westward, and above the Cambrian are the Ordovician, Carboniferous and probably Permian. These are found in rather wide beds, the Permian extending westward to within ten miles of Sundance. From this point westward to Sundance the Triassic red sandstone covers the entire valley, extending to the northward and southward many miles, while the Paleozoic rocks bend to the eastward as they encircle the main uplift. Throughout this area artesian wells can be secured, and although the bands of rock do not reach high up along the hills, one can expect a large supply of water, since the precipitation in this section of the state is almost double that of central Wyoming. North and east of Sundance the conditions are very favorable. The Bear Lodge mountains traverse considerable country north and south. They have a core of Cambrian rocks and the Ordovician, Carboniferous and Permian flank either side. The elevation of the highest peak is 6,750 feet. These rocks furnish water for the western side of the basin, that is supplied from the east by the Black Hills. At Sundance good wells will be secured if drilled to a depth of 1,000 or 2,000 feet. On the west side of the Bear Lodge range is also a second area that will be found productive. Westward on the Belle Fourche river there is an anticlinal fold in Cretaceous rocks, in the Belle Fourche oil field, but this is of little importance for artesian water, on account of a slight production and the contamination with petroleum.

Having dealt with the exterior of this, the largest artesian basin in Wyoming, some may inquire what is to be done with the central region, where streams are scarce and water is so badly needed. Very unfortunately the best water-bearing zones are buried so deep with upper Mesozoic rocks that any attempt to pierce them with a drill would prove futile. In reality this is the most valuable portion of the basin if it were possible to drill and reach the Dakota sandstone or the Paleozoic rocks, but unless there are new inventions that will aid us in drilling, no one need for a moment consider drilling a well deeper than 5,000 or 6,000 feet, and since a well here would have to be from 10,000 to 20,000 feet deep to reach the great water zones, it makes the question hinge on impossibilities. Even in the central regions slight flows may be found near the surface that would repay many times the expense of drilling. In the Salt Creek oil fields artesian water bands have been found, but the water was so saturated with sodium sulphate as to render it useless for any purpose. Along the fold of the Powder River oil basin wells may be found, but if associated with the oil sands they will not be useful. On account of the Dakota sandstones cropping to the surface in this section, there is an excellent opportunity to drill along the axis of the anticlinal fold and secure a large supply of water that would come from the Big Horn mountains. The Oil Mountain oil field should also be included as a possible place for securing a flow. In fact the Guthery well, which is drilled on Poison Spider creek, has furnished a small flow of sulphur water for several years. Wells drilled nearer the axis of the fold should produce more water.

See Section X for geological structure of Powder River artesian basin.

THE GREEN RIVER ARTESIAN BASIN.

The area of this basin is very great, but the boundary lines cannot be surely fixed, since there are no mountain ranges that act as barriers, and also because the Tertiary rocks have obscured the greater portion of the Mesozoic and Paleozoic terranes. The Rawlins uplift marks the eastern limit, but as this only extends a few miles, it only establishes a portion of the boundary. From the Rawlins uplift the line extends south to the western flank of the Sierra Madre range, thence south to the Colorado line. To the northward it extends to Green mountain. The northern boundary extends from Green mountain northwest to South Pass, thence north and west to the great bend of the Green River and thence southwest along the Gros Ventre mountains. The western border is formed by the Gros Ventre mountains and lesser folds that extend southward outcropping occasionally between Lead creek and at a point just west of Opal, thence due south to the Colorado line; but all, or nearly all, of the older sedimentary rocks are buried beneath the Tertiary. The southern boundary is in reality in Colorado, where the Uinta mountains form a higher barrier, with the Paleozoic and Mesozoic rocks dipping toward Wyoming. Conditions about the basin are different from any described. There are some high mountains but the strata do not as a general thing extend high up along the ranges. For miles none of the Mesozoic and Paleozoic rocks are exposed and if they ever did flank the range they have been completely buried by more recent sediment. At Rawlins there is an Archaean exposure, but the sedimentary rocks reach a higher elevation than the granites. To the west of the Archean the Paleozoic rocks, which are Cambrian, Carboniferous and probably Permian dip to the westward at a higher inclination and also gradually decrease in elevation toward the Red desert. The Mesozoic rocks, apparently conformable, dip at a less angle and at a distance of ten or fifteen miles, the Laramie rocks dip only a few degrees to the west. South of Rawlins the dip of the strata gradually flattens, and only the Cretaceous series appear on the surface. Along the Sierra Madre the Cretaceous rocks rest upon the Algonkian schists. The drainage from this range may enter the Cretaceous at various intervals, or it may follow the unconformability to a great depth. North of the Rawlins uplift artesian conditions disappear. The Cretaceous rocks are folded, but form a rough and broken country that is bordered on the west with Eocene Tertiary rocks, and the north by an elevated region known as Green mountain, the structure of which is not definitely known. Possibly Green mountain may act as a storage reservoir, but with this exception there are no elevations to produce hydrostatic pressure. To the west of the Rawlins uplift slight flows may be looked for, and these may be secured many miles west of Rawlins: but large wells should never be expected. Along the Sierra Madre mountains, the question of artesian water cannot be settled without drilling. Surface conditions do not warrant an opinion.

The northern boundary of this basin, from Crook's gap westward, is a broad Tertiary plateau, which practically forms the northern boundary of the Red desert. To the southward the plateau terminates in precipitous bluffs which rise from 500 to 1,000 feet above the desert, and reach in almost an unbroken line from just west of Crook's gap nearly to Pacific Springs. Throughout this entire distance there is no evidence of any rocks older than the horizontal Tertiary strata, that alike covers the table land and the desert. Mesozoic rocks are below; but how deep one would have to drill to reach them no one can tell. Prior to the deposition of the Tertiary, the Cretaceous rocks flanked the Wind River range. These rocks seem to have suffered greatly from erosion along the southern and western slopes and later their upturned edges were entirely buried by the Tertiary. At the foot of the escarpments along the desert it may be possible to drill and reach some of the Cretaceous bands. At present there are no indications to follow, since there are only a few small springs known that have their origin in the Tertiary. From Pacific Springs north and west conditions are similar until within a few miles of the great bend of the Green river, where both Mesozoic and Paleozoic outcrop. These escarpments are very small, however, and give but little promise of important water supplies. West of the Green river, along the southern and eastern slopes of the Gros Ventre mountains, the sedimentary rocks lie high up on the range and offer similar inducements for drilling as have been cited along several of the other important mountain ranges. Conditions are not exactly the same, since the Tertiary strata obscures the most of the Cretaceous and will make it necessary to drill in the lower Mesozoic bands and in the Paleozoic. Along this range the rocks exposed are the same as formed along the eastern slope of the Wind River mountains.

From the Gros Ventre mountains southward to the state line there is an anticlinal fold along which the lowest exposed rocks belong to the Carboniferous. This exposure is not continuous, for the Tertiary rocks have in many instances covered the entire fold. It is especially prominent northward from Opal on the Oregon Short Line railroad. Between the Gros Ventre range and Opal there are no high mountains, and the Carboniferous rocks must be considered the lowest zone in which to look for artesian water, and in this only small flows can be expected. On account of the Tertiary covering most of the Mesozoic the most desirable locations for drilling will be found along a narrow band paralleling the Carboniferous exposure. South of Opal the entire fold is covered with Tertiary, which debars it from artesian possibilities.

The southern boundary of the basin is in reality the Uinta mountains. In Wyoming there is a narrow belt of the uppermost Cretaceous bands that extend from Black's Fork nearly to Dixon. While flowing wells may be found in this region, the locality is unfavorable, on account of coal veins and poor water. Further, the supply would be quite small and if good water could be found the production would not warrant the expense.

Some mention should be made of the central part of this basin. At Salt Wells and to the south there is a broad anticlinal fold which causes the rocks to dip westward to Rock Springs and eastward to Black Buttes. To the east the surface gradually rises so that very little depth is gained. Toward Rock Springs the surface falls rapidly but does not equal the dip. On this account flowing wells can be obtained in the vicinity of Rock Springs and to the north and south some distance. They can be found by drilling at Green River city. None of these localities are recommended: First, on account of the numerous coal veins, which always produce bad water; and second, on account of the abundance of soda salts found in this region. Wells drilled at Green River in which the water rose to the surface and at times flowed, have contained as high as 24 per cent of sal soda or sal soda mixed with other soda salts. Artesian wells have been drilled at Rock Springs, and a small flow obtained; but the water was anything but desirable.

See Section XI for geological structure of Green River artesian basin.

THE SWEETWATER VALLEY.

Since the structure of this valley is very questionable and thus far has not been entirely satisfactorily explained, it can not be called an artesian basin. The valley extends from the North Platte river westward between the Seminoe, Ferris and Green mountains on the south and the Rattlesnake mountains on the north, nearly to Lewiston. All of this area is covered with Tertiary (probably Miocene) except the low round granite masses that have been called the Sweetwater mountains. The largest granite areas extend along the northern side of the Sweetwater river from below Devil's Gate westward nearly to Rongis. The highest peaks are not over 1,000 feet above the valley. The masses are irregular in outline, with numerous low and long narrow ridges extending out into the valley. The slopes are smooth and contain little or no soil, but there are occasional grass patches or a few scrubby pine trees. The peaks are dome shaped and are worn so smooth that it is usually very difficult to scale them. In all cases the Tertiary rocks are found lying upon or against the granite. Besides the large masses of granite there are numerous outliers and these are often very small, only a few acres in extent. These outlying exposures are widely scattered and are to be found not only in the center of the valley but also along the Rattlesnake and Ferris mountains. So far as investigation has proven, there are no Paleozoic or Mesozoic rocks exposed in this region. Along the Ferris mountains the Tertiary was found resting upon the Archæan and across the valley the Rattlesnake mountains so far as known present the same features. Along the Ferris range the Paleozoic dips at high angle to the southward while along the Rattlesnake these rocks dip to the northward. At first one is inclined to consider this valley the axis of a great anticlinal, with the ranges on either side representing what was at one time the base of a broad and high range. On a second thought it seems more likely that this valley was an Archæan land mass and that it continued to be an island from the beginning of the Archæan up to the close of the Eocene Tertiary. Following this period the granite highland was depressed and covered by a Miocene sea, but the peaks and highest ranges protruded above the lake surface. Prior to this valley becoming a Tertiary sea the Ferris and also the Rattlesnake mountains were in all probability elevated by means of enormous faults which paralleled the valley. In case this solution is true the granite peaks of the Sweetwater valley represent the only portions of Wyoming that have been constantly above sea since the beginning of geological time. Again, if this solution is true, the Sweetwater valley is not an artesian basin, and while wells may be found by drilling, no one should expect a flow.

See Section XII for geological structure of the Sweetwater valley.

THE LARAMIE ARTESIAN BASIN.

This ideal basin lies between the Laramie and Medicine Bow mountains, being limited in its southern extension by the union of the Laramie and Medicine Bow mountains and on the north by the westward bend of the Laramie mountains, which forms the eastern boundary, and on the west by the Carbon and Shirley artesian basins, which boundary is a north and south line passing just west of the western termination of the Como anticlinal. In the northern half of the Laramie basin there is a local anticlinal fold extending from the old Miser siding north and east nearly to the Big Laramie river, and a second one north of Rock Creek which has the same strike as the Miser and is several miles in length. West and north of these is the Como anticlinal and a portion of the anticlinal north of Medicine Bow, which influences the strata as much as either of those previously mentioned.

The rocks forming this basin include all of the periods known in the Rocky mountain geology from the Carboniferous to the Fox Hills inclusive. Along the Laramie mountains the Carboniferous and Permian lie high up along the range, often reaching an elevation of from 1,000 to 1,500 feet above the valley and dipping gently, about 12 degrees, to the westward. In reality these rocks form the western slopes of the range and on this account there is not a single stream that forms from springs along the mountain side that reaches the Laramie river, on account of the water following the bedding planes and supplying the artesian basin. The conditions along the southern end of the basin cannot be as clearly shown, since the rocks are badly distorted, faulted, and in many places they dip at a high angle northward and are largely covered with soil. Along the Medicine Bow mountains the dip of the rocks is very sharp, often reaching 60 degrees, and on account of the soil and talus washed from the range they are as a rule buried. In the Centennial valley, which lies between Sheep mountain and the main range, there is a small area in which the rocks are not very thick, since they have suffered exceptional erosion and not less than 10,000 feet of sedimentary rocks have been removed. In consequence the entire strata in this region are not over 4,000 feet thick in the center of the valley and the rocks dip gently from both the east and tne west and likewise from the south. North along the Medicine Bow range the Carboniferous rocks seem to rest upon the Archæan or Algonkian and can be seen occasionally where the streams issue from the mountains. Sometimes they are found higher up than along the Laramie range. The greatest difference between the eastern and western sides of this basin is that on the east the rocks dip gently and the oldest sedimentary rocks extend a long distance from the crest of the range, while along the western side the rocks approach the vertical and are only seen in narrow bands. (For illustration, see geological section of the Laramie basin.)

Along the northern end of the basin the Carboniferous rocks are gently inclined to the south and form a broad band that disappears beneath the Tertiary on nearing Sheep creek. Above the Carboniferous there is a broad band of Triassic sandstone. These gently dipping strata will furnish a considerable amount of water. For this section, the Laramie mountains must be considered as the primary source for the water, which is slightly augmented by the flow from Freezeout hills. The slight uplifts near Miser, Rock Creek, Como and Medicine Bow also affect this whole region. Along the anticlinals the axes have been eroded down to the Triassic and in the one north of Medicine Bow to the Permian or Carboniferous. Between these folds are slight synclinal basins which may prove valuable for small wells. There are a few springs that act as overflows for this section. One is at Como, another at Seven Mile spring, north of Rock Creek, and a third at Boswell springs. These folds have been beneficial to a certain degree, for they have caused the Cretaceous bands to be removed and made it possible to reach the Carboniferous and the Archæan a long distance from the Laramie mountains.

The mountains on three sides of this basin furnish the water supply for this basin. On the plains the average rainfall is about 12 or 14 inches, but in the Medicine Bow mountains it is double if not treble that amount. A considerable portion ot this snow, which melting, gradually follows the strata on their downward course and this basin is filled to the overflowing, the overflows being springs in various places along the ranges. Along the foot of the Laramie mountains there are the Laramie, Soldier Creek, Simpson, Red Buttes and Sportsman lake springs, all of which appear to come from a slight fault. The large springs in the Centennial valley are also vents.

The most important water-bearing horizons are the Carboniferous, Permian, Triassic, and Dakota Cretaceous. Above these bands good wells may be secured in which the water will be questionable. Along the western boundary of the basin the above formation cannot be seriously considered, since as a rule they are found high up along the range where water is not needed. Below, along the valley, the depth will be too great to penetrate with a drill. The Centennial valley is an exception to the above, for at any point in the valley it will be possible to drill to the granite. Artesian wells, however, will be found by drilling in the Cretaceous rocks along the Medicine Bow mountains. The chances for securing good water are about equal to the chances for securing poor.

Along the eastern side of the basin conditions are exceptionally favorable for well drilling to secure water in the Carboniferous, Permian and Triassic rocks. There is a belt varying from three to six miles in width the entire length of the basin, where wells drilled from 200 to 3,000 feet can secure good flows of excellent water, the deep wells having preference and producing the largest volume of water.

At the present time numerous experiments have been tried in the Laramie basin and they have usually been successful. Quite a number of wells have been drilled in and about Laramie. These vary in depth from 200 to 1,500 feet and the water has usually been found, but the flow only moderate. It is only fair to remark that had they used larger tools the production of each well would have been increased. So far as known, the wells drilled at Laramie have all been in Triassic sandstone and but a few of them have been drilled deep enough to reach the Permian or Carboniferous rocks, where the best wells will be found. I would suggest that the most valuable water-bearing horizon lies near the granite, where there is a coarse sandstone. At Laramie a well would have to be drilled about 2,000 feet to reach this zone, which in all probability will furnish a surprising water supply. Along the western edge of the basin four wells have been drilled, three of which flow, and in the fourth water would rise to within 18 inches of the surface. The water of two of these wells was excellent. The others were sulphurous and contained considerable sodium sulphate. The good wells secured their flow in the Fox Hills sandstones. The water supply of the Laramie plains can be greatly augmented by drilling artesian wells. The basin is large, has a vast area tributary to supply water which can not only be utilized for ranch and municipal purposes, but to a considerable extent for irrigation. What is most needed today is a deep well that should be drilled a good distance west of the Laramie range and deep enough to reach bed-rock.

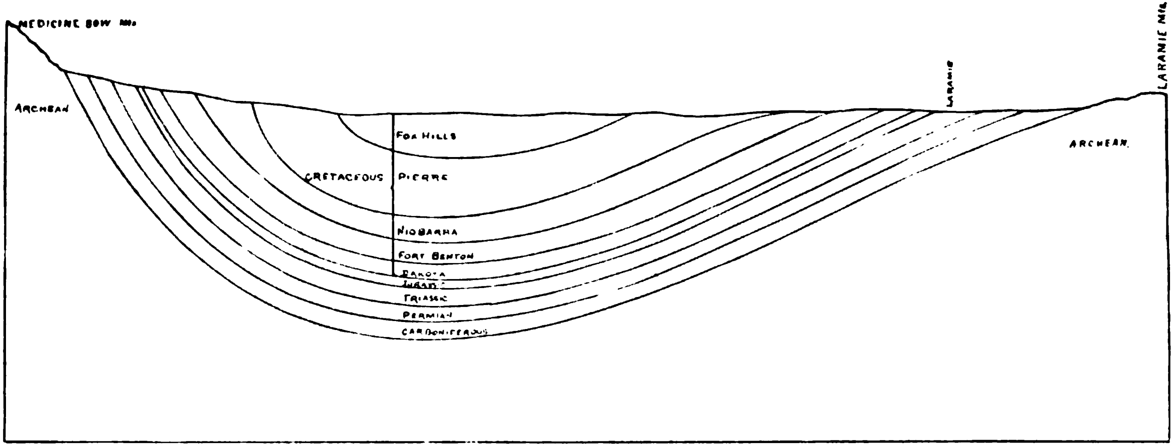
How many wells this basin will support and give to them all a reasonable supply can not be estimated. However, the area is large and the water supply is more than ordinary. By drilling wells the pressure must of necessity be decreased, but this will not be apparent until the demand exceeds the supply.

See Section XIII for geological structure of the Laramie artesian basin.

THE SHIRLEY ARTESIAN BASIN.

Lying east of the North Platte river and north of the Shirley mountains there is a depression that has been known for years as Shirley basin, but this must not be confused with the Shirley artesian basin, which is very much larger. The artesian basin includes all of the territory lying between the Laramie mountains on the north and the Shirley mountains and Freezeout hills on the south. There are no natural barriers hemming in this basin on the east or west. The North Platte river can be considered the western boundary and a line extending north from the eastern termination of the Freezeout hills the eastern. Along the Laramie mountains the Tertiary strata have covered nearly all of the earlier sedimentary rocks. Near the Platte river, where the waters have cut a broad val-

SECTION XIII.



A geological section of the Laramie artesian basin, extending from the Laramie mountains westward through Laramie to the Medicine Bow mountains.

[Drawn to Scale.]

ley, the Tertiary rocks have been entirely removed and exposed the formations from the Archæan upwards. Hence along the river there is a narrow band of exposures which are bordered on either side by Tertiary beds, and which will produce some artesian wells. From a point a few miles below the mouth of the Sweetwater river, where the Platte river surges through the great canon, the sedimentary rocks dip to the north. Passing down the canon one can see along the walls the Cambrian, Carboniferous, Permian, Triassic, Jurassic, and the very base of the Cretaceous, when suddenly the Carboniferous or Permian rocks are duplicated and rise at least 400 feet above the Cretaceous. This sudden change has been due to a fault which extends for a considerable distance on either side of the Platte river and possibly is the southeastern termination of the great fault that produced the Rattlesnake mountains. From this fault flows several warm springs which have been credited with remarkable medicinal properties. The water has a temperature of 140 degrees F. At any point above the fault artesian wells may be drilled and a flow obtained. The Platte river crossing these strata at nearly right angle as it passes through the canon, furnishes them with an unusual supply of water. Below the fault, the Paleozoic rocks are covered with gently dipping Mesozoic bands which are capped with Laramie. Below Alcova ten miles is the axis of a synclinal basin which extends northwest and southeast, beyond which the strata rise gradually toward the Laramie range. On either side of the synclinal basin, that is, near Alcova or near the Laramie range, wells can be drilled in the Triassic and possibly in the Fort Benton and a medium flow obtained. Were it not for the water supply of the Platte river this section would be of no value for artesian water.

From the Platte river eastward* along the range there are

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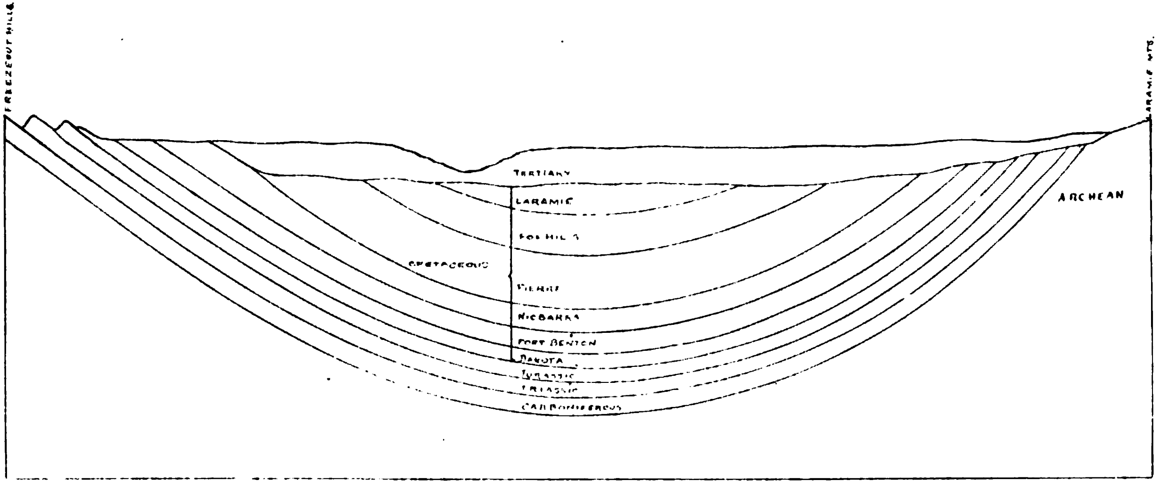
*Since the geological map was drawn I have investigated Bates Hole and found that the central portion of this area has been eroded down to the Cretaceous. The Cretaceous exposure along the Platte river should extend in a narrow belt some thirty miles east and south.

SECTION XIV.



Geological section from the Freezeout hills northeast to the Laramie mountains, across the Shirley artesian basin.

[Drawn to Scale.]

no places where surface indications would warrant anyone in searching for artesian water. Along the Shirley mountains the Tertiary has also covered the upturned sedimentary rocks from the Platte river eastward to the head of Muddy creek. From the head of Muddy creek along the range as far as Freezeout hills, the Paleozoic strata are exposed and are nearly vertical, dipping slightly to the northeast. Below, in the valley, are the Mesozoic rocks, which extend for several miles northward, when they disappear beneath a high Tertiary bluff. All along the range between the last points mentioned, wells may be found by drilling near the mountain base. A better method would be to tunnel for the water in the section.

Along the Freezeout hills the oldest exposed rocks are either Permian or Carboniferous which do not rise to any considerable height above the valley lands. All of the Mesozoic rocks are present and the Dakota band forms the slopes of the hills. These are cut in numerous places by gulches and ravines in which there are a few small springs. By drilling in the Dakota bands and penetrating the Triassic sandstones flowing wells can be obtained. The flow will not be strong and the water may be strongly impregnated with gypsum.

See Section XIV for geological structure of the Shirley artesian basin.

THE CHEYENNE ARTESIAN BASIN.

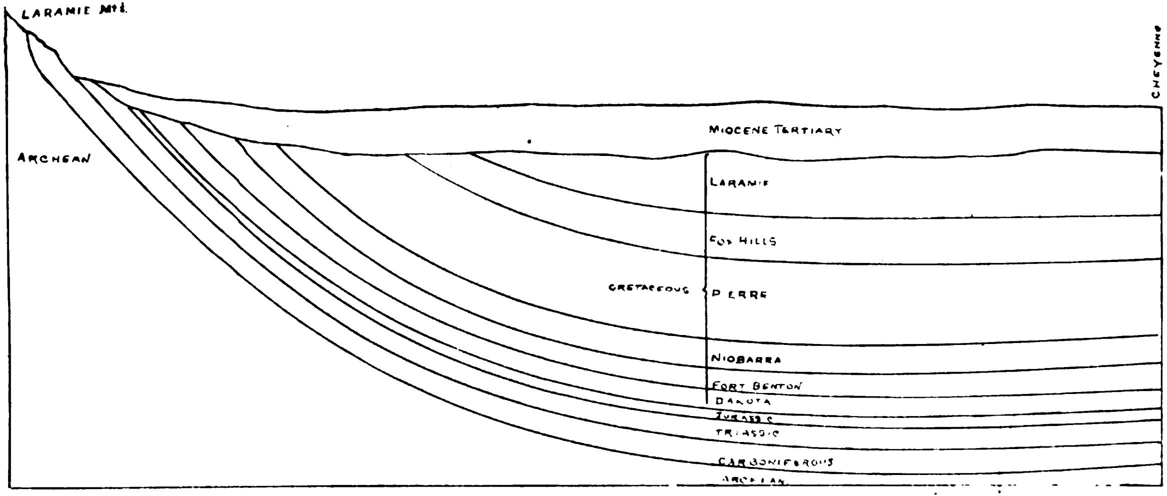
This basin differs from most of the artesian basins of the state. In the first place, the mountains are found along the western side only, the eastern and southern borders having no barrier and the strata extending into Colorado and Nebraska. The Carboniferous rocks exposed to the westward of Cheyenne outcrop at Omaha. Secondly, the water-bearing rocks were originally and are to a great extent at the present time covered with Miocene Tertiary. Nevertheless there are artesian possibilities in the Cheyenne basin, which is bounded on the north by the Powder river basin, on the west by the Laramie mountains, and extending on the south into Colorado and the east into Nebraska. Along the Laramie mountains the Paleozoic rocks, which are composed of simply the Carboniferous or Carboniferous and Permian, stand in nearly a vertical position, except at Table mountain, where a large block of limestone has been carried up by the granite and is an isolated area nearly level. To the northward of Table mountain, along Pole creek, Horse creek and Chugwater, the Carboniferous can be seen as huge hog-backs paralleling the range. Similar exposures are seen south of Table mountain. Occasionally there are exposures of the Triassic sandstone accompanying the Carboniferous and in a few instances the Tertiary has been removed in the valleys, laying bare the Cretaceous rocks as high as the Fort Pierre shales. In localities where the Mesozoic and Paleozoic rocks are exposed and the strata are not vertical, artesian wells may be found, but the water supply will be small, since these strata depend upon the rainfall for their water.

In Goshen hole the Tertiary rocks have been removed from quite large areas, and the Laramie sandstones exposed. Artesian water will be found in this depression, but on account of the coal the water may be very impure. Again, the supply of water from wells drilled in this region will never be very great. North of the Big Laramie river, and especially along the Platte river and extending eastward to the Hartville hills, the geology is entirely different from the southern half of the basin. Here not only the Tertiary rocks have been removed, but also the Mesozoic, leaving the Carboniferous exposures. To the westward of the canon of the Platte there is a synclinal basin, in which there are some Cretaceous rocks. Representing the oldest strata along the Laramie mountains are the Carboniferous and Cambrian rocks extending high up along the mountain slopes. This produces a basin of considerable importance, and wells drilled in the Dakota or lower will unquestionably find an abundance of excellent water. All of the limestone area between the Cheyenne and Northern railroad and Hartville can be considered as artesian territory. Wells will not have to be drilled deep and the flow will not be large. Eastward from Hartville conditions are unfavorable for well drilling. The Tertiary country lying east of Whalen canon will probably never have a flowing well. The rocks to be encountered below the Tertiary are the Laramie, which are quite liable to furnish very inferior water. In case an artesian well is contemplated at Cheyenne in the future they should arrange to drill not less than 4,000 feet. But in any case it is very questionable if a well would ever pay the necessary expense. In this connection it is well to recall some of the wells that have been drilled in the Tertiary that do flow small streams of good water. One of these is south of Cheyenne. In the Tertiary there are lenses of clay that are impermeable layers, and these confine a small quantity of water that is taken up by the ground and carried to lower levels. The Tertiary dip slightly to the eastward, which accounts for the artesian pressure. Small wells may be found near the surface, but since the clay bands are local well drilling will be mere guess-work.

In the Cheyene basin the conditions are such that in the future it may be found advisable to drill wells near the mountains, where they would not be so deep, and pipe the water to lower levels. The great springs at Granite Canon reveal the fact that there is quite a large water storage along the Laramie mountains west of Cheyenne, and that this spring acts as the overflow for the basin.

See Section XV for geological structure of the Cheyenne artesian basin.

SECTION XV.



Geological section from the Laramie mountains eastward through the Cheyenne artesian basin to Cheyenne.

[Drawn to Scale.]

Medicine Bow anticlinal can be considered as valuable territory for small wells.

The southern boundary presents many peculiar phases. The Medicine Bow range rises to a height of over 12,000 feet, but separating it from the Sierra Madre there is a broad valley that has been filled with Tertiary and the Sierra Madre mountains are largey Algonkian, about which nothing older than the Cretaceous rocks have been found. Elk mountain forms the northern termination of the Medicine Bow mountains, and about this very prominent peak are bent the Paleozoic and Mesozoic strata, the Paleozoic lying high up along the slopes and continuing to a considerable distance to the eastward and to the southward. About this mountain there is ample room for many wells, all of which should be large producers. The best flow will be obtained by drilling through the Paleozoic and reaching bed-rock. In the Platte valley, in the vicinity of Saratoga, all of the Mesozoic and Paleozoic strata have been covered with the Tertiary. At Saratoga there is evidence, in the warm springs, which are justly celebrated for their medicinal qualities, that there are some large faults that bring the heated water supply to the surface. It is very probable that the Saratoga valley is a synclinal basin between the two ranges. If this is the case, wells may be found of some importance by drilling through the Tertiary strata at points near the ranges.

The Sierra Madre range presents several features that have not been studied and the country about the base of this range cannot be recommended for artesian wells, but nevertheless a careful investigation might prove it of some importance.

The interior of the Carbon basin is largely made up of the Laramie Cretaceous and cannot be considered as artesian territory on account of the great depth it would be necessary to sink to reach a flowing water zone.

THE UINTA ARTESIAN BASINS.

In Uinta county, south of the Gros Ventre mountains, there are several anticlinal folds that extend south towards the Utah line. For this reason I have used the term basins, instead of basin, for there are several anticlinal folds that will prove to be of some value in securing flowing wells. Unfortunately, much of this area is covered with Tertiary rocks, which seriously interfere with working out the stratigraphical conditions. So far as investigation has gone, there are two prominent anticlinals extending north and south. The axis of the first passes just west of Opal and the second west of Twin Creek. These folds are exposed to some extent along the line of the Union Pacific railroad and also north of the Oregon Short Line railroad. The rocks exposed, so far as known, are the Carboniferous, and these are nearly all north of the Oregon Short Line railroad, and do not form very high ranges. In some instances the axis has been deeply dissected but the Ordovician or Cambrian rocks have not been reported. On account of these sedimentary ranges being low and not accumulating much snow, the basins in this region will not produce large flows Again, on account of the slight elevation of the surrounding country, the pressure will also be insufficient to produce a large flow, provided the water supply is sufficient.

In the country north of Opal, and along the Carboniferous exposures, wells will be found by drilling in the lowest exposures of the Carboniferous or Triassic rocks. Wells obtained in these bands will undoubtedly produce the greatest water supply and will also furnish the most desirable water. Wells drilled in the Jurassic will without question secure water in the Triassic sandstone provided they are drilled to a depth of 500 feet or more. It will also be possible to drill in the Jurassic bands and reach the Carboniferous water supply with deep wells. In no instance can the Cretaceous bands be recommended for artesian wells. They are water-producing and slight flows may water zones lie beneath the Dakota sandstones in this as in nearly all of the basins in Wyoming.

THE TETON ARTESIAN BASIN.

This basin lies on the west of the Teton mountains and is in reality tributary to Idaho. The formations entering into its structure, as far as exposed, are largely Paleozoic. The Cambrian, Ordovician and Carboniferous extend up the mountain slopes to perpetual snow. Along this range artesian conditions are ideal, but the demand for artesian water in Wyoming from this source will never amount to anything, since there are abundant streams to provide all the water that the Wyoming area of the Teton will ever need. For this reason the basin has been merely mentioned.

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